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VOLUME I OF III

12

TASK ANALYSIS REPORT RELATIVE TO VESSEL COLLISIONS, RAMMINGS, AND GROUNDINGS

DECEMBER 1976

FINAL REPORT

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15. Supplementary Notes Three volumes: Volume I contains an overview of the analysis, findings, and recommendations, plus supporting Appendices A-E. Volumes II and III contain task data in Appendices F and G (for tankers and towboats, respectively).

16. Abstract The report describes the processes and results of analysis of tasks of bridge personnel on tankers and other deep draft cargo vessels and on towboat-barge arrays. The Functional Job Analysis (FJA) method of task analysis was applied. The report provides a data base of comparable and concise descriptions of the tasks required for vessel control using currently available onboard equipment, information, and external aids. The data base includes, for each task, the action required, the expected result, equipment/materials/sources of information, degree of prescription/discretion involved, performance standards, and general educational background and job-related training requirements. Ratings of task complexity are provided. The analysis was performed at a generalized level for fleet-wide applicability. The analysis was iterated for three scenarios: mooring/unmooring, maneuvering in restricted waters, and coastal/open sea navigation.

The analytic intent was to establish a baseline for systematic, continuing research into human factors in merchant vessel casualties. In addition, recommendations were made of actions that might be taken in the near term to improve the safety of vessel control operations.

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METRIC CONVERSION FACTORS

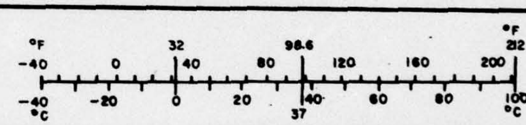
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This is a final report on the analysis of vessel control tasks being performed for the U.S. Coast Guard by Operations Research, Inc. (ORI), with assistance from subcontractor Engineering Computer Optecnomics, Inc. (ECO). The analysis is part of Task 2 under Human Factors Requirements Contract No. DOT-CG-41903-A, which began in July 1975. This report forms the technical basis and orientation for conduct of the Coast Guard research and development program in human engineering related to the prevention of collisions, rammings, and groundings.

Dr. John S. Gardenier, of the Coast Guard's Division of Safety and Advanced Technology, was the technical monitor of the project. CDR Benjamin Joyce, of the Division of Merchant Vessel Personnel, was the program officer under whose cognizance the work was done. Both CDR Joyce and Dr. Gardenier were unfailingly available throughout the project to provide feedback on our progress and to advise and assist whenever needed. Their careful review of interim results and their cogent criticisms and suggestions contributed greatly to this report.

ORI and ECO personnel performed the task analysis which was preceded and accompanied by contact with industry, maritime union training organizations, maritime professional associations and research organizations as sources of information and feedback. Observations of tanker bridge personnel were made aboard an oil tanker on route from Texas to New Jersey, operated by Keystone Shipping Company. Observations of towboat control personnel were arranged through Dixie Carriers, Inc., on towboat barge arrays on the Intracoastal Waterway and on a number of river routes. Additional validation of task data was achieved by distribution of task statements to selected industry and union training organizations.

The method of task analysis used was Functional Job Analysis (FJA), developed by Dr. Sidney A. Fine, industrial psychologist. Dr. Fine acted as a consultant to the study team on the application of the method. His experience,

practical advice, and personal interest in the progress of the analysis are acknowledged with appreciation.

Dr. Alphonse Chapanis, human engineering psychologist and professor at The Johns Hopkins University, also consulted with the study team. His insightful criticisms and suggestions are gratefully acknowledged.

EXECUTIVE SUMMARY

This report presents the results of a task analysis of functions performed by merchant marine bridge personnel on tankers/freighters and towboats. The technique of Functional Job Analysis (FJA) was used to document all vessel control tasks. Observations were made by the ORI study team on both categories of vessels. Task statements prepared in the analysis were distributed throughout the maritime community (to unions, industry, training schools) to ensure accuracy of data and to obtain general comments and suggestions. This research was performed under Department of Transportation, U.S. Coast Guard Contract DOT-CG-41903-A.

PURPOSE

The intent of this study was to provide a sound basis for the Coast Guard's human engineering program directed toward the improvement of safety and the prevention of collisions, rammings, and groundings. This task analysis performed by ORI is an initial step in the identification of conditions that may increase the probability of human error in vessel control operations. The analysis provides a data base describing the requirements, normal work flow, and conditions of vessel bridge control which can be used as a foundation for planning future research. The long-range goal of the Coast Guard's human engineering program is to apply the results of this research to decrease marine accidents. Some recommendations for action directed to that end are made on the basis of the task analysis. However, it is stressed that additional research is needed to gain a clearer understanding of the factors that affect the performance of vessel personnel.

GENERAL CONCLUSION

A general conclusion synthesized from the recommendations and observations reported herein is that there is a strong need for various forms of standardization which will promote marine safety. This is reflected in recommendations for standardizing basic equipment designs and data inputs to watchstanders and for increasing crew stability.

RECOMMENDATIONS

1. More standardization of basic equipment characteristics and minimum performance capabilities should be considered to promote transfer of training and minimize unreasonable adaptive demands on the worker.

2. Reliable data are needed on current speed and direction and the interaction of those variables with others (such as channel configuration and placement of natural and man-made features, vessel horsepower and displacement) so that vessel control requirements and limitations may be better understood.

3. The system of aids to navigation should be assessed with particular attention to needs during navigation at night, under conditions of poor visibility, and in segments in which maneuvering requirements are severe.

4. For towboat navigation, there is a need for marking vertical bridge supports (piers) and dikes along the river.

5. Indoctrination to the specific features, characteristics, and procedures of the vessel and its particular equipment should be given to all personnel.

6. More effort should be made to have tanker and other cargo ship personnel remain with the same ship, the same route, and the same bridge crew.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

This report presents results of an analysis of tasks of vessel control performed to assist the Coast Guard in its efforts to improve the safety of merchant vessel operations. This analysis is part of the Coast Guard's human factors research program directed toward the improvement of safety and the prevention of collisions, rammings, and groundings.

Our aim in conducting the task analysis was to create a context that would make it easier to determine, or at least hypothesize, where and when, in the operations of vessel control, accident-inducing human behavior may be likely to occur. We can then more systematically study the possible underlying forms and sources of accident-inducing behavior.[1] The context consists of task data that describe the actions, skills, and knowledge required in vessel control operations using currently available material aids, information, and procedures. The action, skill, and knowledge requirements are overt demands on human capacities. Singly and in combination, the overt demands represent other, often less obvious, physical, intellectual, and emotional demands whose nature and relationships are not well understood. All of these demands may be reasonable or excessive, depending on the individual on whom they are laid and the circumstances. The premise of the task analysis was that, to improve our understanding of human performance in vessel control, it would be necessary to begin by specifying the overt demands. This provides a more orderly context in which to consider underlying demands and to evaluate the safety implications of both in relation to information about performance conditions (including, for example, natural environment, traffic, vessel handling characteristics, social factors onboard, the demography of the population of bridge personnel, etc.).

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[1] "Accident" as used in this report refers only to events in which the vessel, other property, the environment, or all three are affected. The study has not considered events leading to personal injury only.

Lastly, the task analysis as performed in this study is impersonal in the sense that it does not delineate who performs what functions. It covers general functions/tasks that must be accomplished for adequate vessel control, irrespective of who performs any one task or what the vessel organizational structure is.

II. ANALYSIS PLAN

GENERAL STRATEGY

The FJA method was used to document the manning, equipment interfaces, and normal work flow of tanker[2] and towboat control (maneuvering) operations. Initially it was suggested by the Coast Guard that analyses be done for four categories of vessels—an oceangoing tanker, a coastal tanker or freighter, a dedicated hazardous chemical towboat-barge array, and a general cargo towboat-barge array. However, it was found possible to combine the four analyses into two—one for tankers/freighters, and one for towboats. The oceangoing and coastal tankers were treated as one category since the major distinctions in basic task functions occurred between groups of tasks related to navigation in restricted waters (difficult, tight maneuvering) versus navigation in the open sea. Both scenarios, in addition to berthing/unberthing maneuvers, are covered in the tanker task analysis. For towboats, only one analysis was necessary since vessel control operations are essentially the same whether or not hazardous cargo or general cargo is being transported. Differences occur primarily with cargo handling tasks, which are analyzed under Task 3 of the Coast Guard human factors contract (Martino, 1976). Both tanker and towboat analyses cover routine situations and unusual or emergency situations.

Each task analysis captures basic tasks common to different types and sizes of tankers and towboats. The master/captain needs the basic input data, e.g., environmental, equipment feedback information, which enables him to make judgments about speed or course changes, and then to execute one or both of those options. Equipment may differ among types of tankers or varieties of towboat-barge array, but the basic functions, for example, scanning a radar or monitoring a radio, are common to all types of vessel categories. Therefore, each task analysis encompasses all types of vessel within the tanker and towboat categories (in berthing/unberthing, restricted waters, and open sea scenarios). Situations where certain pieces of equipment may not be available

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[2] Throughout this report, the word "tanker" is meant to include both tanker and freighter.

are noted. These situations usually reflect age differences in vessels, e.g., older vessels may not have has much electronic equipment.

The generality of task functions has permitted this analysis to produce an assimilable quantity of task data while addressing a broad range of vessel types, classes, and operating areas. In turn, those task data should facilitate further research into the sources of variance in task performance as well as actions designed to increase the likelihood of successful performance. Future research should certainly include investigations of task performance in the context of particular classes of vessels and operating areas, among other probable parameters of effective performance. This analysis has defined the variables that may be influenced by such specifics.

STEPS IN ANALYSIS PLAN

The steps followed in performance of the task analysis of the vessel control functions are outlined in Figure 1. The figure is designed to point up the fact that although the six activities are performed in sequence, there is much backflow during progress toward completion. For example, system diagramming (Step 2 in the figure) may point up a need for more information (Step 1); task editing (Step 5) may send the analysts back for more information (Step 1). Each step continues, is consulted, and is resumed as needed throughout the analysis. Details of each step are outlined below.

Collect Information

The information gathering step involved an extensive literature search, plus contact with union training organizations and operating companies to obtain any existing vessel control task information and company operating procedures. The literature search focused on five basic areas:

1. General background information, including review of licensing, qualifications, and other pertinent maritime/shipping rules and regulations.

2. Review of marine accident information and accident analyses that have been performed.

3. Investigation of psychological factors and attitudes apparently associated with accident occurrence, including the latest evaluations of the "accident-proneness" hypothesis.

4. Information on existing safety analysis methods that could be of value during or following a task analysis.

5. Previous job or task analyses or other kinds of information about the work of vessel control.

A detailed explanation of how the literature review was accomplished is included in Appendix A, along with an annotated bibliography of documents

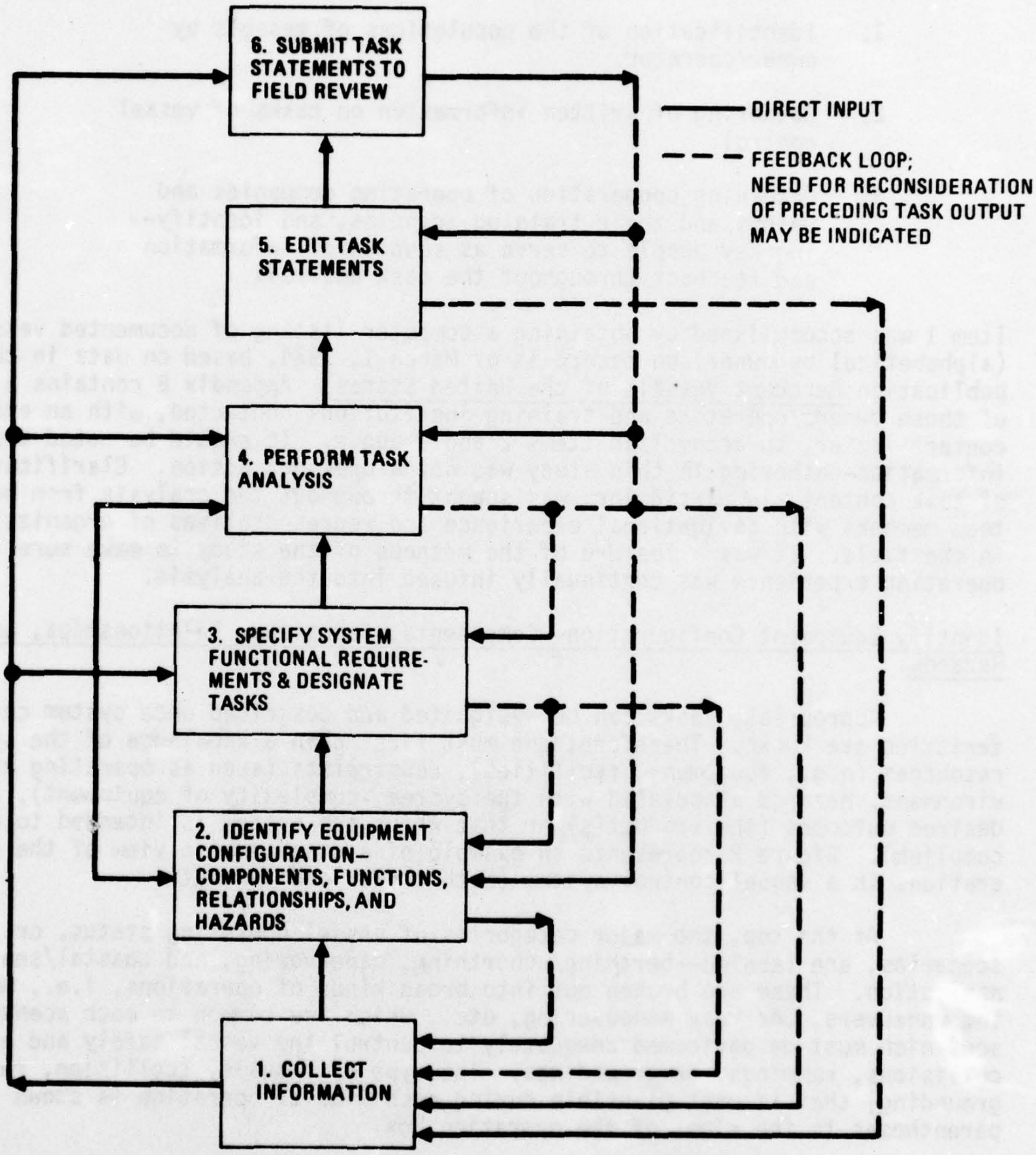

FIGURE 1. OVERVIEW OF STEPS IN TASK ANALYSIS

reviewed and a list of organizations contacted to obtain information in the five areas listed above.

Information from the field was obtained in three general areas:

1. Identification of the populations of vessels by owner/operator.

2. Gathering of written information on tasks of vessel control.

3. Obtaining cooperation of operating companies and unions and their training agencies, and identifying key people to serve as sources of information and feedback throughout the task analysis.

Item 1 was accomplished by obtaining a computer listing of documented vessels (alphabetical by owner) on record as of March 1, 1974, based on data in the publication Merchant Vessels of the United States. Appendix B contains a list of those owners/operators and training institutions contacted, with an example contact letter, to accomplish items 2 and 3 above. It should be noted that information-gathering in this study was not a one-shot action. Clarification of task content, in particular, was sought throughout the analysis from both team members with navigational experience and representatives of organizations in the field. It was a feature of the methods of the study to make sure that operating experience was continually infused into the analysis.

Identify Equipment Configuration—Components, Functions, Relationships, and Hazards

Appropriate tasks can be designated and described once system characteristics are known. Therefore, one must first gain a knowledge of the system resources (e.g., equipment, facilities), constraints (such as operating environment, hazards associated with the system, complexity of equipment), and desired outcomes (the product(s) or that which the system is intended to accomplish). Figure 2 represents an example of a diagrammatic view of the operations in a vessel control system (both tanker and towboat).

At the top, the major categories of vessel operating status, or scenarios, are labeled—berthing/unberthing, maneuvering, and coastal/sea navigation. These are broken out into broad kinds of operations, i.e., mooring maneuvers, underway maneuvering, etc., which are common to each scenario, and which must be performed adequately to control the vessel safely and avoid collisions, rammings, or groundings. The type of casualty (collision, ramming, grounding) that is most plausible during each kind of operation is shown in parentheses to the right of the operation box.

Moving down the chart, the operations are broken out into more specific activities, and the equipment that may be used in performing those activities is identified. Activities not directly related to vessel control are included—namely, supervisory, administrative and training activities.

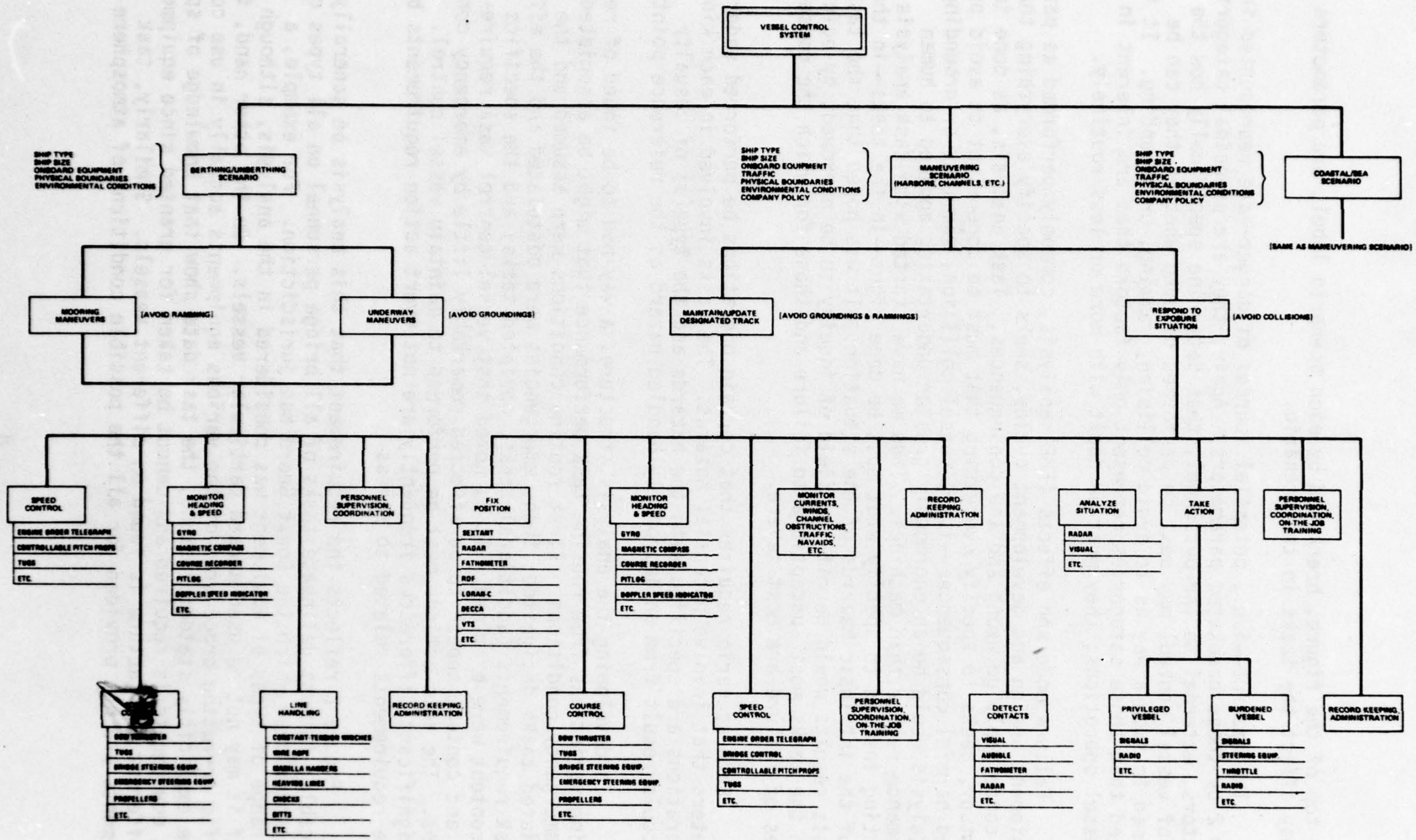

FIGURE 2. OVERVIEW OF THE OPERATIONS IN A VESSEL CONTROL SYSTEM

At the top of the figure, bracketed by each scenario label, are parameters that may affect the tasks in the scenario.

The hazards—i.e., potential sources of danger—are represented in Figure 2 by those bracketed parameters. Again, they are principal categories of factors, external to the personnel, that determine specifically how the tasks of vessel control may best be performed or even whether they can be performed in such a way as to avoid collision, ramming, or grounding. It is stressed that those categories represent only factors that are inherent in the vessel operations; they must be dealt with more or less routinely.

Failure mode and effects (FME) analysis, commonly performed as part of equipment design and development cycles, seeks to specify everything that could conceivably go wrong and the consequences. Task analysis, as done in this study, seeks to specify everything that must be done right to avoid predefined harmful consequences—i.e., vessel collision, ramming, or grounding. FME analysis would be an enormously greater undertaking applied to human performance rather than machines. Thus we have started with task analysis, attempting instead to specify what must be done right—in the tasks—in the face of the intrinsic hazards of the situation. It was hoped that the task analysis results would permit the field of inquiry to be narrowed, by pointing up the tasks most susceptible to failure and those for which the consequences of failure are most severe.

Each scenario requires that certain operations be performed under parameters that involve potential hazards. The tasks involved in each kind of operations are specified with the hazards and the type(s) of casualty that could result from an improperly handled hazard as the reference points.

In developing the analysis structure, a way had to be found of reflecting variations from routine task performance that might be associated with emergency conditions. First routine conditions were assumed and the associated tasks designated; then, emergencies were postulated and the effects on task requirements (additional tasks, obviated tasks) and the specifics of task content were examined. It is noted that vessel control task requirements and content appear to be affected remarkably little by emergency conditions. The same actions must be performed to maintain vessel control. The significant differences frequently are not overt action requirements but subtle requirements related to stress.

Figure 2 reflects the requirement that this analysis be generally applicable; it must delineate tasks of all bridge personnel on all types of cargo ships over which the Coast Guard has jurisdiction. For example, a full range of types of equipment was considered in the analysis, although all of it may not be used aboard particular vessels. On the other hand, the specific operating procedures of the various equipments actually in use could not be explicitly stated; instead, the task data show that knowledge of specific equipments is required and cannot be taken for granted since equipment of different manufacture is found on different vessels. Similarly, task statements are not provided for all the possible conditions of atmosphere

and water which, in combination with the physical characteristics of the harbor area and with vessel size, type and load, may affect mooring arrangements. However, the necessity to take all of these particulars into account during mooring operations is explicitly stated.

Specify System Functional Requirements and Designate Tasks

The next step in preparing for the task analysis was to develop the structure begun in Figure 2 by designating the purpose, goals, and objectives of the system operation. Then the task actions required to accomplish each objective were designated. Figure 3 shows the breakout of the purpose, goals, and objectives for vessel control in the tanker/freighter analysis; Figure 4 shows the breakout for the towboat-barge array. The towboat-barge array system functional outline shows fewer goals, since open sea travel is not appropriate (shown as Goal III in the tanker/freighter outline, Figure 3) and fewer preparations/inspection checks are needed prior to the voyage (shown as Goal I in Figure 3).

To some extent, the layout of the work system in this way was arbitrary. The content of purpose, goals, objectives, and tasks is fairly readily agreed upon in general concept, but they may be stated in a number of ways, with variable scope. However, the FJA four-level breakdown (purpose, goal, objective, task) infers that a purpose be broad enough to comfortably encompass each goal, objective and task. Likewise, a goal and objective must be broad enough to encompass the categories under them.

After the purpose, goals, and objectives were delineated, the tasks required to accomplish each objective were designated. The designation of tasks under each objective then carried the systems analysis to a much more detailed level. As far as level of detail is concerned, a great deal of leeway occurs at this step. A task may be narrow in scope, in which case many are designed, or it may be as broad as the objective, in which case only one task would be designated for the objective. The only requirement is that it must be an action or action sequence that contributes to the accomplishment of an objective. However, tasks that are extremely narrowly defined are difficult to work with for most purposes, and tend to reduce the actual complexity of the work. This approach may be desirable, as, for example, when an organization wants to create jobs for workers who have little education and work experience, and very limited skills. The work is delineated in very small units which are then combined to define jobs that put minimal requirements on the workers. However, there seems to be no point in doing such an analysis of vessel control operations, at least when the analysis is directed toward improving personnel qualifications and conditions of the operations to increase the margin of safety. For such a purpose it is best to call a "task" a whole action or closely integrated action sequence as performed in current operations.

Figures 5 and 6 show listings of the task designators for all the objectives in the first goal of the tanker and towboat analyses, respectively. A complete list of designated tasks for all objectives in each analysis is in Appendix C.

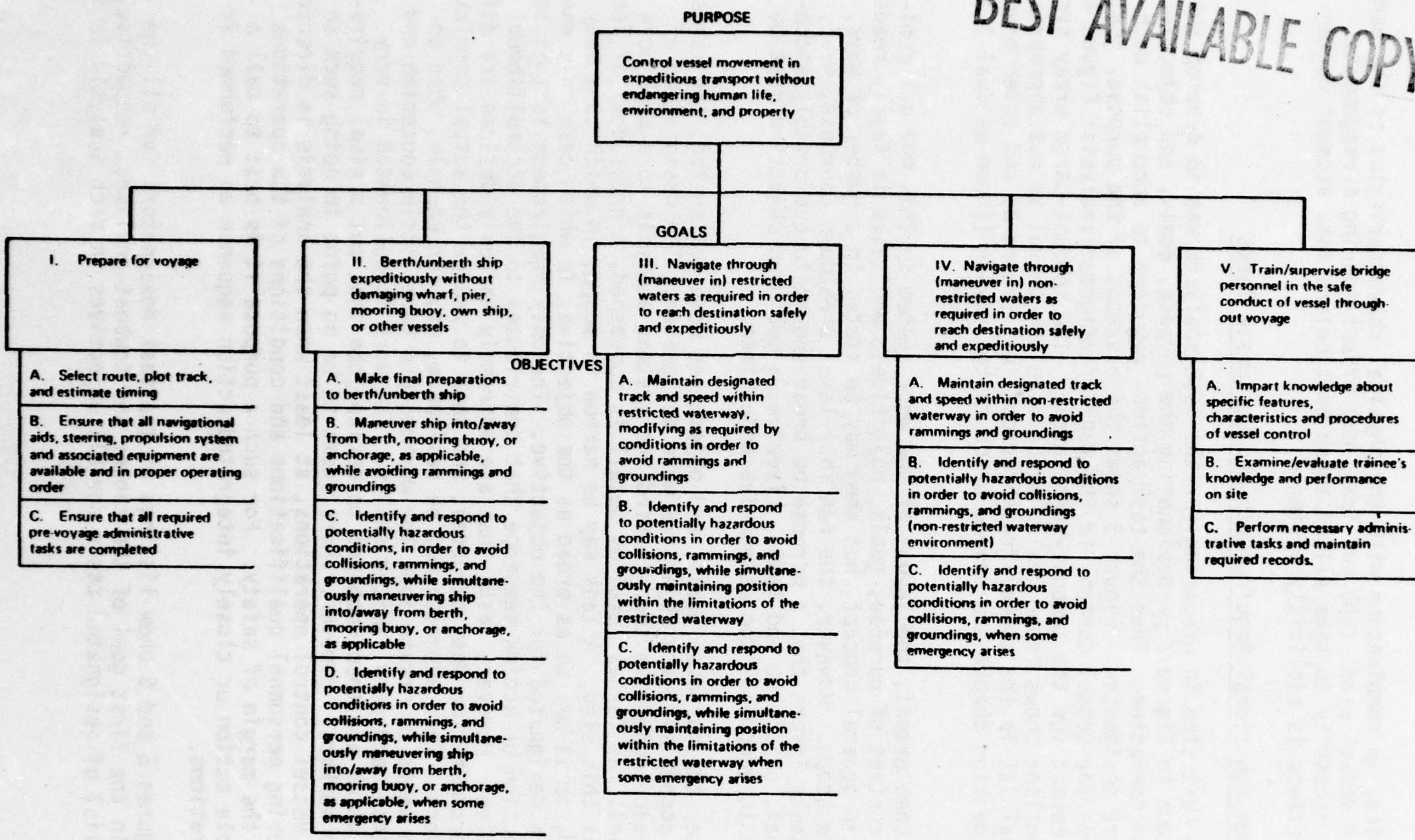

FIGURE 3. PURPOSE, GOALS AND OBJECTIVES OF TANKER/FREIGHTER SYSTEM OPERATIONS

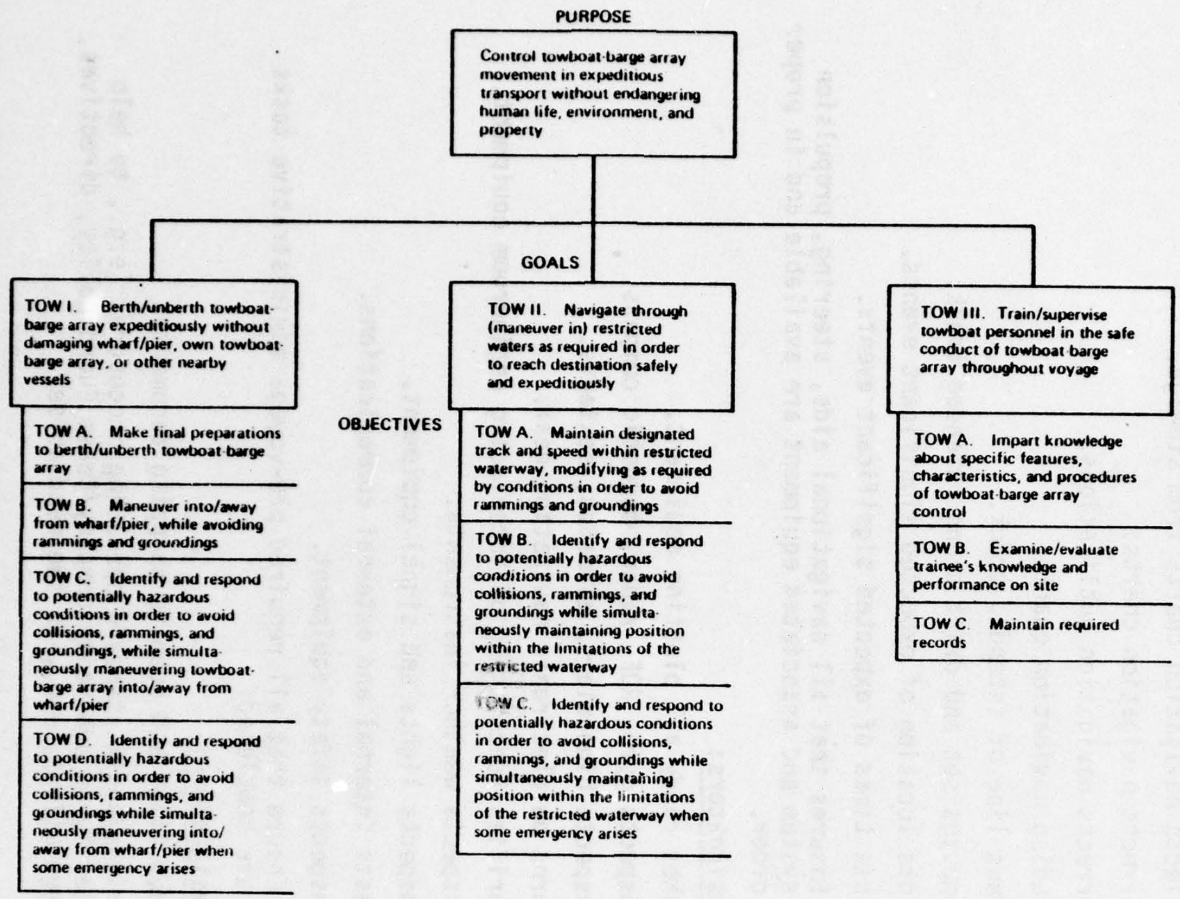

FIGURE 4. PURPOSE, GOALS AND OBJECTIVES OF TOWBOAT-BARGE SYSTEM OPERATIONS

Goal I: Prepare for voyage.

Objective I.A: Select route, plot track, and estimate timing.

Task Designators:

1. Selects navigation charts from stowage.
2. Corrects navigation charts.
3. Corrects navigation publications.
4. Studies navigation charts.
5. Draws line of intended track.
6. Computes set and drift along intended track.
7. Plots location of expected significant events.
8. Lists times of expected significant events.

Objective I.B: Ensures that all navigational aids, steering, propulsion system and associated equipment are available and in proper order.

Task Designators:

1. Makes ready all plotting equipment.
2. Inspects gyro, RDF, radar, magnetic compass.
3. Inspects binoculars, alidades, sextants.
4. Turns on electronic navigation gear.
5. Verifies functioning of interfacing engineroom equipment.
6. Inspects weather instruments.
7. Inspects lights and signal equipment.
8. Tests internal and external communications.
9. Inspects safety equipment.

Objective I.C: Ensure that all required pre-voyage administrative tasks are completed.

Task Designators:

1. Identifies and submits shipping documents.
2. Writes/posts standard operating procedures (e.g., to help clarify or publicize company/Coast Guard policy, directives, regulations, etc., as the need arises.

FIGURE 5. LISTING OF TASK DESIGNATORS FOR GOAL I OF TANKER/FREIGHTER ANALYSIS

Goal TOW-I: Berth/unberth towboat-barge array expeditiously without damaging wharf/pier, own towboat-barge array, or other nearby vessels.

Objective TOW-I.A: Make final preparations to berth/unberth towboat-barge array.

Task Designators:

1. Ascertains towboat-barge array's draft.
2. Ascertains port's characteristics and rules.
3. Estimates wind and current direction and speed.
4. Communicates with port authorities.
5. Exchanges maneuvering information with other vessels.
6. Reviews standard and emergency maneuvers.
7. Evaluates all pertinent information.
8. Supervises making and breaking of towboat-barge array.

Objective TOW-I.B: Maneuver into/away from wharf/pier, while avoiding rammings and groundings.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Examines and evaluates total data input.
7. Adjusts towboat's RPM.
8. Turns towboat's helm.
9. Sounds whistle and displays signals.

Objective TOW-I.C: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering towboat-barge array into/away from wharf/pier.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Monitors collision avoidance system.
7. Assesses other vessel traffic in area.
8. Examines and evaluates total data input.
9. Adjusts towboat's RPM.
10. Turns towboat's helm.
11. Sounds whistle and displays signals.

Objective TOW-I.D: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering into/away from wharf/pier when some emergency arises.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Monitors collision avoidance system.
7. Assesses other vessel traffic in area.
8. Evaluates total data input during non-towboat-control emergency.
9. Evaluates total data input during towboat-control emergency.
10. Adjusts towboat's RPM.
11. Turns towboat's helm.
12. Sounds whistle and displays signals.

FIGURE 6. LISTS OF TASK DESIGNATORS FOR GOAL I OF TOWBOAT-BARGE SYSTEM OPERATIONS

In general, the process of designating system functional requirements in the form of purpose, goals, and objectives and associated tasks was an evolutionary process. Initial designations were revised as each lower level breakdown was made. The taxonomy had to have logical integrity and needs for revision asserted themselves as the taxonomy was developed. During the process, the scope and content of each level was questioned to assure that it was a logical outgrowth of the preceding level and appropriate input to the next. The end product of this step in the analysis plan, the lists of task designators shown in Appendix C, are not full task descriptions. They merely identify the tasks to be described and analyzed. The methodical approach to task designation outlined above provided a means to verify that all important tasks were included in the proper sequence and that no inappropriate tasks were included.

Perform the Task Analysis

Once the tasks have been designated, the actual task analysis begins. The procedures for delineating a task in FJA task statement form have been described in previous ORI reports, including a handbook (Stoehr *et al.*, 1976) and three demonstration studies (Porricelli *et al.*, 1976; Hall *et al.*, 1976; and Martino, 1976) and in the publications of Dr. Sidney A. Fine, the originator of FJA (Fine and Wiley, 1971; Fine, 1973; Fine *et al.*, 1974). Therefore, the detailed procedures will not be explained here; however, an overview (excerpted from the handbook) is provided in Appendix D for quick reference.

Figure 7 is an example of a completed task statement. It is an actual statement from Goal I, Objective A in the tanker/freighter analysis. The goal (1) and objective (2) are shown on the task sheet. The task statement (3) shows the action being performed ("Computes direction and velocity of current"), the equipment needed to perform that action ("using tidal current charts, ... and knowledge of ..."), and the result ("in order to determine ... "). Once the task description is formulated, the FJA scales are applied to rate the task on various levels of orientation (4)—attention to people, data, things; on worker prescription (5); and on degree of mental/linguistic abilities required to perform task (6). The complete set of FJA scales are in Appendix E.

Once the task description is formulated and rated, sections on the performance standards (7) and training content (8) are completed. The performance standards establish the rigor with which a task must be performed to do it properly in a specific work environment or under particular work conditions. These standards provide the basis for evaluating performance of candidates, either in a test or on-the-job situation. The standards are also important for the development of training and training outcomes.

The FJA method calls for specification of numerical or categorical performance standards. All vessel control tasks are, at least potentially, safety critical, but it is difficult to describe a degree of criticality outside the context of specific conditions. Thus it is difficult to set standard ranges of acceptable accuracy. The approach decided upon was to set a 100 percent criterion for evaluating the result in all cases in which a faulty task result could conceivably result in a collision, ramming, or

TASK CODE: I.A.6

WORKER FUNCTION LEVEL AND ORIENTATION (4)						WORKER INSTRUCTIONS (5)	GENERAL EDUCATIONAL DEVELOPMENT (6)		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	80	1A	5	3A	15	3	4	4	4

TASK CODE: I.A.6 GOAL: Prepare for voyage. (1)

OBJECTIVE: Select route, plot track, and estimate timing. (2)

TASK: Computes the direction and velocity (set and drift) of the current at various points along the route for the estimated duration of voyage, using tidal current charts, current diagrams, and knowledge of time of departure and estimated speed of advance, in order to have ready that part of the information needed to determine courses and speeds throughout the voyage. (3)

PERFORMANCE STANDARDS (7)	TRAINING CONTENT (8)
<u>Descriptive:</u> ● Properly estimates set and drift of current. <u>Numerical:</u> ● In 100% of the cases, calculates required ship courses and speeds over the ground in order to remain on track.	<u>Functional:</u> ● How to use current charts and current diagrams. ● How to calculate set and drift. ● How to compensate for set and drift. <u>Specific:</u> ● Knowledge of time of departure and estimated speed of advance for particular voyage.

FIGURE 7. EXAMPLE OF A COMPLETED TASK STATEMENT

grounding. It will be noted that nearly all tasks have a 100 percent criterion (or an equivalent categorical statement), which says a great deal about rigors of the work of vessel control. The tasks may be and often are simple, but they must be done properly. That is not to say the system cannot tolerate any task omission or faulty performance; but there is no guarantee of tolerance. There are few work systems in which it is so important to life, limb, and public welfare to do things right. The 100 percent criterion is therefore put forth as the rational _goal_ for task performance, although it is recognized that people do not work with 100 percent accuracy and that the system usually will tolerate some degradation.

With regard to training, FJA involves specification of two types. The first is general training which provides basic skills and knowledge applicable in any work setting in which the task is performed. This type of training is usually provided in schools and develops through experience over time. The second type is training needed to accomplish a task in a particular work setting. Specific training relates to particular machines, environments, people, or systems within an organization. Since the analysis here is applicable to many different work settings (e.g., to different classes of ship operating in different waterways and using different harbors and terminal facilities) it is difficult to get very specific about "specific training content." The procedure adopted was to reference the type of situation-specific information/skills that a worker would need to do the task. By that means, a user of the task data may know what orientation in the work setting is required to provide a basis for satisfactory task performance.

The information needed to write the task description, to accurately rate the task according to the FJA scales, and to outline performance and training standards was obtained from

- Available documentation in the form of navigational textbooks (e.g., Hill, _et al._, 1959; Turpin and MacEwen, 1965; Dutton, 1957; Noel and Chandler, 1965; Wentworth, _et al._, 1957)
- Documentation in the form of company operating procedures (provided mainly by Chevron and Exxon); both are reputed to be leaders in the industry for documentation on bridge operations and safety
- Navigational experience of study team members
- Contact with people in industry and training schools who have knowledge of ship control tasks
- Observation aboard vessels to obtain up-to-date information and any omitted details.

Observation aboard vessels is discussed in the following parts of this section. The fully completed FJA task statements for the tanker/freighter and towboat-barge array analyses are in Appendices F and G, respectively, which are each bound separately.

Edit Task Statements

After all task statements were written, members of the study team, B. Paramore, J. Smith, P. Daniels, J. Porricelli and V. Keith (all of whom had been trained in the FJA technique) edited the task statements. Consultant Sidney A. Fine also edited samples of statements from all Goals. The editing procedure assured that all content elements were included and clearly stated, that the assigned FJA scale ratings were representative of task requirements, that performance standards and training content were usable operationally and logically supportable by other parts of the task statement, and that the whole task statement gave a sense of reality about the task action and its context. A complete summary of the steps in the editing process are included in the overview of FJA procedures in Appendix D mentioned earlier.

Submit Task Statements to Field Review

The purpose of the field review is to validate the task statements by obtaining feedback from people who are most knowledgeable about the system under analysis. The field review answers the questions:

- Do the task statements communicate the same thing to all concerned readers?
- Does everyone concerned agree that the task statements represent reality?

Differences of opinion are resolved by discussion and, when necessary, by writing and comparing task descriptions that reflect the differing opinions. The in-house edit can help answer the above questions initially. However, the field personnel's knowledge of actual operating procedures is immensely helpful in obtaining an accurate, realistic set of task statements. For this reason we carried out a two-stage field review of written FJA statements. The first step consisted of sending copies of statements to representatives of organizations in the field. We contacted the three major maritime union training schools (Maritime Institute of Technology and Graduate Studies; Seafarers International Union of North America; National Maritime Union Upgrading and Retraining School) and two shipping companies (Keystone Shipping Company Dixie Carriers, Inc.) to help with the field review of task statements.

The second step in the field review process involved actual observation aboard vessels. Study team members with navigational experience conducted onboard observation during a six-day trip on an oil tanker (mixed products, 37,000 DWT) along a coastal route from the Shell Refinery at Deer Park, Texas, to the Shell Distribution Facility at Sewaren, New Jersey. Three towboat trips were made covering a total of approximately 2,500 miles:

1. Up the lower and upper Mississippi River aboard a towboat (with a tow of oil barges) from Gretna, Louisiana, to Vicksburg, Mississippi.

2. Along the Intracoastal Waterway on a towboat—(10 LASH) barge array from Louisa Bridge west of Morgan City, Louisiana, east to New Orleans.

3. Down the Ohio River from Cincinnati to Memphis, Tennessee (on the Mississippi Rover).

The trip down the Ohio River was made during flood conditions, thus providing an example of a more severe environmental condition. The trips provided the opportunity to make observations along a number of different types of routes and conditions—coastal route, Intracoastal Waterway, pooled river, major river junctions, upstream and downstream travel, etc. In addition to making observations onboard the towboats, numerous, lengthy informal conversations were carried on with other towboat operators along the route via ship-to-ship communication (on low-traffic channels, after contact was made initially on the common channel).

The onboard observations allowed the study team to see the normal work flow and check on the completeness and accuracy of tasks developed in the analysis. They were present during a variety of different work-activity and environmental scenarios, i.e., berthing/unberthing, maneuvering in restricted waters, open sea navigation, and were able (at least in towboat observations) to view vessels with different kinds and types of equipment. Since the observers had seagoing experience and were thoroughly trained in FJA, they were able to evaluate the accuracy and completeness of the written task statements through observation and from informal conversations with the crew. They also could get a feeling for the reasonableness of job demands, for time duration/frequency ranges of individual tasks, and for the general kinds of data inputs and physical and mental stresses/demands experienced by the crew. Informal discussions of task operational and environmental difficulties also helped to verify the task statements in particular and illuminate the area of vessel safety in general.

No questionnaire was used since discussions with managers of the companies hosting the observations indicated that extensive note-taking and questionnaires would have a negative effect. The following topics were discussed: difficult maneuvering situations; near misses, accidents and their causes; sources of information relied upon for vessel control decision-making; use of bridge-to-bridge radiotelephone; how the work of vessel control is learned; what makes a good vessel handler.

Most persons interviewed had difficulty pinpointing specific "safety critical" tasks, supporting our viewpoint that each task could be potentially safety critical, but that it is difficult to describe a degree of criticality outside the context of specific conditions.

The discussions of results of the task analysis which follows in the next section of this report synthesizes the information received from the onboard observations and insights from task analysis, per se.

III. RESULTS OF TASK ANALYSIS

This section is divided into two parts. The first part contains a discussion of the insights gained from the task analysis and from review of the completed task statements. The major emphasis of this discussion is on a schematic representation of the information flow in vessel control. This schema provides the framework for many of our recommendations. The recommendations are outlined in the second part of this section.

INSIGHTS FROM TASK ANALYSIS

Repetition of Tasks

The analysis clearly showed that there is a limited number of basic tasks which must be performed, but that there is much repetition in the performance of these tasks. Figure 8 shows a listing of the task designators for Goal II of the tanker/freighter analysis (berthing/unberthing maneuvers). By reading down the list, one can see that the tasks tend to repeat themselves from objective to objective. In addition, the asterisked tasks in Figure 8 are repeated throughout objectives in other goals also. While certain parts of the complete task statement may differ for repeated tasks (particularly for those repeated across goals), the basic function outlined in the task description is the same. This shows that a small number of highly repetitive tasks are being performed, regardless of the environmental scenario, i.e., berthing/unberthing, navigation in restricted waters, navigation in open seas, and regardless of the work environment, i.e., normal vs. emergency situation. The repetition of a relatively small number of tasks could possibly lead to extended time spans characterized by boredom, inattention, and/or a particular mind-set or habitual (rote) response pattern, thus lessening the probability that the person would act spontaneously, flexibly and alertly in a given situation.

Goal II: Berth/unberth ship expeditiously without damaging wharf, pier, mooring buoy, own ship, or other vessels.

Objective II.A: Make final preparations to berth/unberth ship.

Task Designators:

1. Ascertains ship's draft.
2. Ascertains port's characteristics and rules.
3. Monitors wind direction and speed.
4. Communicates with port authorities.
5. Communicates mooring information to crew.
6. Reads pilot and tug information.
7. Exchanges maneuvering information with other ships.
8. Reviews standard and emergency maneuvers.
9. Evaluates all pertinent information.

Objective II.B: Maneuver ship into/away from berth, mooring buoy, or anchorage, as applicable, while avoiding rammings and groundings.

Task Designators:

*1. Visually scans waters around berth.
*2. Operates radar and fathometer for hazard and aid detection.
*3. Monitors wind direction and speed.
*4. Reads course and speed indicators and alarms.
*5. Monitors voice radio.
6. Determines anchor drop range or bearing.
*7. Examines and evaluates total data input.
*8. Conveys navigation orders to other personnel.
*9. Adjusts ship's RPM.
*10. Turns ship's helm.
11. Utilizes mooring lines, anchor chain, etc.
12. Communicates with tugs, linehandlers, etc.
*13. Sounds whistle and displays signals.

* These tasks are commonly repeated throughout other goals of the tanker analysis.

FIGURE 8. LISTING OF TASK DESIGNATORS FOR GOAL II OF TANKER/FREIGHTER ANALYSIS

Objective II.C: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering ship into/away from berth, mooring buoy, or anchorage, as applicable.

Task Designators:

*1. Visually scans waters around berth.
*2. Operates radar and fathometer for hazard and aid detection.
*3. Monitors wind direction and speed.
*4. Reads course and speed indicators and alarms.
*5. Monitors voice radio.
6. Determines anchor drop range or bearing.
*7. Monitors collision avoidance system.
*8. Assesses other vessel traffic near berth.
*9. Examines and evalutes total data input.
*10. Conveys navigation orders to other personnel.
*11. Adjusts ship's RPM.
*12. Turns ship's helm.
13. Utilizes mooring lines, anchor chain, etc.
14. Communicates with tugs, linehandlers, etc.
*15. Sounds whistle and displays signals.

Objective II.D: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering ship into/away from berth, mooring buoy, or anchorage, as applicable, when some emergency arises.

Task Designators:

*1. Visually scans waters around berth.
*2. Operates radar and fathometer for hazard and aid detection.
*3. Monitors wind direction and speed.
*4. Reads course and speed indicators and alarms.
*5. Monitors voice radio.
6. Determines anchor drop range or bearing.
*7. Monitors collision avoidance system.
*8. Assesses other vessel traffic near berth.
*9. Evaluates total data input during non-ship-control emergency.
*10. Evaluates total data input during ship-control emergency.
*11. Conveys navigation orders to other personnel.
*12. Adjusts ship's RPM.
*13. Turns ship's helm.
14. Utilizes mooring lines, anchor chain, etc.
15. Communicates with tugs, linehandlers, etc.
*16. Sounds whistle and displays signals.

FIGURE 8. (Cont)

Time Duration and Frequency Ranges of Tasks

Upon completion of the task analysis, the study team outlined task time duration and frequency data, based on the shipboard observations and on the seagoing experience of study team members. During the shipboard observations, study team members stood watches with the bridge personnel over a period of several days. Observations were made in all previously defined scenarios (Figure 2). No prepared checklists were used; nor were task initiation and duration timed with watches and recorded. However, the observers had ample opportunity to sample the tasks performed in each scenario and to note by being involved in the work setting approximately how often and for what duration the various tasks were performed on those sailings.

It should be kept in mind that we had no way of testing the degree to which the task frequency and duration estimates presented herein are representative of the fleet. Seagoing experience supports the view that the estimates are reasonable averages for routine operating conditions. As discussed below, considerable variance in task frequency and duration occurs and is appropriate for different operating conditions.[3] Thus the estimates provided should not be interpreted as absolutes.

The frequency and time duration estimates for the single performance of each task in the tanker and towboat analyses are shown in Tables 1 and 2, respectively. The tasks are listed by goals and objective, and the explanatory legend (key) is at the end of each table. The frequency and duration data entries represent relative values along 5-point scales. The frequency scale ranges from the task being "performed once or less per 4- or 6-hour watch" to being "performed continuously." The duration scale ranges from the tasks being "15 seconds in length" to "ongoing."

The indicated numbers represent performance tempo under average conditions to be expected within each scenario, i.e., berthing/unberthing, navigation in restricted waters, etc. Unusual situations, such as a very narrow, sinuous channel, extraordinarily heavy traffic, or limited visibility in fog, could significantly change actual frequency and duration from the estimated values.

There are a few tasks for which the performance is so tied to an ever-changing or non-standard environment that a single frequency evaluation

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[3] Discussions with the operators indicated that formal observations using checklists and watches would not be well received. Since it was beyond the scope of the project to conduct observations on representative samples of vessels and since our primary purpose was to check the validity of the FJA task data that had been prepared, the rigor of timed, formal observations seemed to be unjustified and counterproductive. A time and motion study being conducted concurrently with this task analysis, by the Oceanographic Institute of Washington (State) is expected to provide more and more precise data on the frequency and duration of tasks performed by key bridge personnel. Extrapolation, however, may be limited in that case as well.

TABLE 1

FREQUENCY AND TIME DURATION RANGES FOR TASKS IN TANKER/FREIGHTER ANALYSIS

GOAL I:

Objective A – Select route and plot track

TASK NO	TASK STATEMENT	FREQ	DUR
1	Selects navigation charts from stowage	1	1
2	Corrects navigation charts	1	3
3	Corrects navigation publications	1	3
4	Studies navigation charts	2	2
5	Draws line of intended track	1	3
6	Computes set and drift along intended track	3	2
7	Plots location of expected significant events	1	3
8	Lists times of expected significant events	1	3

Objective B – Ensure all equipment is onboard and operating

TASK NO	TASK STATEMENT	FREQ	DUR
1	Makes ready all plotting equipment	1	2
2	Inspects gyro, RDF, radar, magnetic compass	1	3
3	Inspects binoculars, alidades, sextants	1	2
4	Turns on electronic navigation gear	1	2
5	Verifies functioning of interfacing engineroom equipment	1	2
6	Inspects weather instruments	1	2
7	Inspects lights and signal equipment	1	2
8	Tests internal and external communications	1	3
9	Inspects safety equipment	1	3

Objective C – Complete pre-voyage administration

TASK NO	TASK STATEMENT	FREQ	DUR
1	Identifies and submits shipping documents	1	3
2	Writes standard operating procedures	1	4

GOAL II:

Objective A – Make final preparations

TASK NO	TASK STATEMENT	FREQ	DUR
1	Ascertain ship's draft	1	2
2	Ascertain port's characteristics and rules	1	3
3	Monitors wind direction and speed	1	1
4	Communicates with port authorities	1	2
5	Communicates mooring information to crew	1	1
6	Reads pilot and tug information	1	2
7	Exchanges maneuvering information with other ships	2	2
8	Reviews standard and emergency maneuvers	1	2
9	Evaluates all pertinent information	5	5

TABLE 1 (Cont)

Objective B – Maneuver into/away from berth

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	3	1
3	Monitors wind direction and speed	3	1
4	Reads course and speed indicators and alarms	4	1
5	Monitors voice radio	5	5
6	Determines anchor drop range or bearing	1	2
7	Examines and evaluates total data input	5	5
8	Conveys navigation orders to other personnel	4	1
9	Adjusts ship's RPM	4	1
10	Turns ship's helm	4	1
11	Utilizes mooring lines, anchor chain, etc.	1	3
12	Communicates with tugs, linehandlers, etc.	4	1
13	Sounds whistle and displays signals	2	1

Objective C – Maneuver into/away from berth while avoiding collision

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	3	1
3	Monitors wind direction and speed	3	1
4	Reads course and speed indicators and alarms	4	1
5	Monitors voice radio	5	5
6	Determines anchor drop range or bearing	1	2
7	Monitors collision avoidance system	4	1
8	Assesses other vessel traffic near berth	5	5
9	Examines and evaluates total data input	5	5
10	Conveys navigation orders to other personnel	4	1
11	Adjusts ship's RPM	4	1
12	Turns ship's helm	4	1
13	Utilizes mooring lines, anchor chain, etc.	1	3
14	Communicates with tugs, linehandlers, etc.	4	1
15	Sounds whistle and displays signals	3	1

Objective D – Maneuver into/away from berth when some emergency occurs

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	3	1
3	Monitors wind direction and speed	3	1
4	Reads course and speed indicators and alarms	4	1
5	Monitors voice radio	5	5
6	Determines anchor drop range or bearing	1	2
7	Monitors collision avoidance system	4	2
8	Assesses other vessel traffic near berth	5	5
9	Evaluates total data input during non-ship control emergency	5	5
10	Evaluates total data input during ship-control emergency	5	5
11	Conveys navigation orders to other personnel	4	1
12	Adjusts ship's RPM	4	1
13	Turns ship's helm	4	1
14	Utilizes mooring lines, anchor chain, etc.	1	3
15	Communicates with tugs, linehandlers, etc.	4	1
16	Sounds whistle and displays signals	4	1

TABLE 1 (Cont)

GOAL III:

Objective A – Maintain designated track and speed

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	3	2
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	3	1
4	Obtains visual ranges and bearings to aids	4	1
5	Obtains electronic indications of position	3	1
6	Monitors wind direction and speed	3	1
7	Reads course and speed indicators and alarms	3	1
8	Monitors voice radio	5	5
9	Examines and evaluates total data input	5	5
10	Conveys navigation orders to others	3	1
11	Adjusts ship's RPM	3	1
12	Turns ship's helm	3	1
13	Sounds whistle and displays signals	2	1

Objective B – Maneuver in restricted waters while avoiding collision

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	3	2
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	3	1
4	Obtains visual ranges and bearings to aids	4	1
5	Obtains electronic indications of position	3	1
6	Monitors wind direction and speed	3	1
7	Reads course and speed indicators and alarms	3	1
8	Monitors voice radio	5	5
9	Monitors collision avoidance system	3	1
10	Assesses other vessel traffic in area	5	5
11	Examines and evaluates total data input	5	5
12	Conveys navigation orders to other personnel	3	1
13	Adjusts ship's RPM	3	1
14	Turns ship's helm	3	1
15	Sounds whistle and displays signals	3	1

Objective C – Maneuver in restricted waters when emergency occurs

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	3	2
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	3	1
4	Obtains visual ranges and bearings to aids	4	1
5	Obtains electronic indications of position	3	1
6	Monitors wind direction and speed	3	1
7	Reads course and speed indicators and alarms	3	1
8	Monitors voice radio	5	5
9	Monitors collision avoidance system	3	1
10	Assesses other vessel traffic in area	5	5
11	Evaluates total data input during non-ship control emergency	5	5
12	Evaluates total data input during ship-control emergency	5	5
13	Conveys navigation orders to other personnel	3	1
14	Adjusts ship's RPM	3	1
15	Turns ship's helm	3	1
16	Sounds whistle and displays signals	4	1

TABLE 1 (Cont)

GOAL IV:

Objective A – Maintain designated track and speed

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	2	2
2	Visually scans surrounding waters	3	1
3	Operates radar and fathometer for hazard and aid detection	2	2
4	Obtains visual ranges and bearings to aids	2	1
5	Obtains electronic indications of position	2	2
6	Monitors wind direction and speed	2	1
7	Reads course and speed indicators and alarms	2	1
8	Monitors voice radio	5	5
9	Examines and evaluates total data input	5	5
10	Conveys navigation orders to other personnel	2	1
11	Adjusts ship's RPM	1	1
12	Turns ship's helm	2	1
13	Sounds whistle and displays signals	1	1

Objective B – Maneuver in non-restricted waters while avoiding collision

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	2	2
2	Visually scans surrounding waters	3	2
3	Operates radar and fathometer for hazard and aid detection	2	2
4	Obtains visual ranges and bearings to aids	2	1
5	Obtains electronic indications of position	2	2
6	Monitors wind direction and speed	2	1
7	Reads course and speed indicators and alarms	3	1
8	Monitors voice radio	5	5
9	Monitors collision avoidance system	4	1
10	Assesses other vessel traffic in area	5	5
11	Examines and evaluates total data input	5	5
12	Conveys navigation orders to other personnel	3	1
13	Adjusts ship's RPM	1	1
14	Turns ship's helm	3	1
15	Sounds whistle and displays signals	3	1

Objective C – Maneuver in non-restricted waters when emergency occurs

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	2	2
2	Visually scans surrounding waters	3	2
3	Operates radar and fathometer for hazard and aid detection	2	2
4	Obtains visual ranges and bearings to aids	2	1
5	Obtains electronic indications of position	2	2
6	Monitors wind direction and speed	2	1
7	Reads course and speed indicators and alarms	3	1
8	Monitors voice radio	5	5
9	Monitors collision avoidance system	4	1
10	Assesses other vessel traffic in area	5	5
11	Evaluates total data input during non-ship-control emergency	5	5
12	Evaluates total data input during ship-control emergency	5	5
13	Conveys navigation orders to other personnel	3	1
14	Adjusts ship's RPM	1	1
15	Turns ship's helm	3	1
16	Sounds whistle and displays signals	4	1

TABLE 1 (Cont)

GOAL V:

Objective A – Train crew in vessel control

TASK NO	TASK STATEMENT	FREQ	DUR
1	Interviews and evaluates new personnel	1	3
2	Conducts indoctrination tour of ship	1	4
3	Maintains standard reference information	1	4
4	Provides on-the-job training	5	5

Objective B – Evaluate trainee's knowledge and performance

TASK NO	TASK STATEMENT	FREQ	DUR
1	Observes trainee and discusses performance	5	4
2	Discusses problems with trainee	1	3

Objective C –

TASK NO	TASK STATEMENT	FREQ	DUR
1	Manages and organizes bridge team personnel	1	5
2	Records required information		1

LEGEND:

FREQUENCY SCALE

1 – Performed once or less per 4-hour watch
2 – Performed once per hour
3 – Performed once every 5 to 10 minutes
4 – Performed once every minute or less
5 – Performed continuously

DURATION SCALES

1 – 15 seconds in length
2 – 1 to 5 minutes in length
3 – 10 to 30 minutes in length
4 – 1 to 2 hours in length
5 – Ongoing

NOTE: Blank in Frequency column = task performed as required.

TABLE 2

FREQUENCY AND TIME DURATION RANGES FOR TASKS IN TOWBOAT ANALYSIS

GOAL I:

Objective A – Make final preparations

TASK NO	TASK STATEMENT	FREQ	DUR
1	Ascertains towboat-barge array's draft	1	2
2	Ascertains port's characteristics and rules	1	3
3	Estimates wind and current direction snd speed	2	1
4	Communicates with port authorities	1	2
5	Exchanges maneuvering information with other ships	3	1
6	Reviews standard and emergency maneuvers	1	2
7	Evaluates all pertinent information	5	5
8	Supervises making and breaking of towboat-barge array	1	3

Objective B – Maneuver into/away from berth

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	1	1
3	Estimates wind and current direction and speed	3	1
4	Reads course and speed indicators and alarms	1	1
5	Monitors voice radio	5	5
6	Examines and evaluates total data input	5	5
7	Adjust towboat's RPM	4	1
8	Turns towboat's helm	4	1
9	Sounds whistle and displays signals	2	1

Objective C – Maneuver into/away from berth while avoiding collision

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	1	1
3	Estimates wind and current direction and speed	3	1
4	Reads course and speed indicators and alarms	1	1
5	Monitors voice radio	5	5
6	Monitors collision avoidance system	1	1
7	Assesses other vessel traffic in area	5	5
8	Examines and evaluates total data input	5	5
9	Adjusts towboat's RPM	4	1
10	Turns towboat's helm	4	1
11	Sounds whistle and displays signals	3	1

Objective D – Maneuver into/away from berth during shipboard emergency

TASK NO	TASK STATEMENT	FREQ	DUR
1	Visually scans waters around berth	5	5
2	Operates radar and fathometer for hazard and aid detection	1	1
3	Estimates wind and current direction and speed	3	1
4	Reads course and speed indicators and alarms	1	1
5	Monitors voice radio	5	5
6	Monitors collision avoidance system	1	1
7	Assesses other vessel traffic in area	5	5
8	Evaluates total data input during non-towboat-control emergency	5	5
9	Evaluates total data input during towboat-control emergency	5	5
10	Adjusts towboat's RPM	4	1
11	Turns towboat's helm	4	1
12	Sounds whistle and displays signals	4	1

TABLE 2 (Cont)

GOAL II:

Objective A – Maintain designated track and speed

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	1	1
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	1	1
4	Obtains visual ranges and bearings to aids	5	5
5	Operates radar and fathometer for navigational position	1	1
6	Estimates wind and current direction and speed	3	1
7	Reads course and speed indicators and alarms	1	1
8	Monitors voice radio	5	5
9	Studies bridges and bridge supports		2
10	Studies canal locks		2
11	Examines and evaluates total data input	5	5
12	Adjusts towboat's RPM	4	1
13	Turns towboat's helm	4	1
14	Grounds towboat-barge array intentionally		3/4
15	Extricates towboat-barge array from grounding		2
16	Sounds whistle and displays signals	2	1

Objective B – Maneuver in restricted waters while avoiding collision

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	1	1
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	1	1
4	Obtains visual ranges and bearings to aids	5	5
5	Operates radar and fathometer for navigational position	1	1
6	Estimates wind and current direction and speed	3	1
7	Reads course and speed indicators and alarms	1	1
8	Monitors voice radio	5	5
9	Studies bridges and bridge supports		2
10	Studies canal locks		2
11	Monitors collision avoidance system	1	1
12	Assesses other vessel traffic in area	5	5
13	Examines and evaluates total data input	5	5
14	Adjusts towboat's RPM	4	1
15	Turns towboat's helm	4	1
16	Grounds towboat-barge array intentionally		3/4
17	Extricates towboat-barge array from grounding		2
18	Sounds whistle and displays signals	3	1

Objective C – Maneuver in restricted waters during onboard emergency

TASK NO	TASK STATEMENT	FREQ	DUR
1	Studies intended track	1	1
2	Visually scans surrounding waters	5	5
3	Operates radar and fathometer for hazard and aid detection	1	1
4	Obtains visual ranges and bearings to aids	5	5
5	Operates radar and fathometer for navigational position	1	1
6	Estimates wind and current direction and speed	3	1
7	Reads course and speed indicators and alarms	1	1
8	Monitors voice radio	5	5
9	Studies bridges and bridge supports		2
10	Studies canal locks		2
11	Monitors collision avoidance system	1	1
12	Assesses other vessel traffic in area	5	5
13	Evaluates total data input during non-towboat-control emergency	5	5
14	Evaluates total data input during towboat-control emergency	5	5
15	Adjusts towboat's RPM	4	1
16	Turns towboat's helm	4	1
17	Grounds towboat-barge array intentionally		3/4
18	Extricates towboat-barge array from grounding		2
19	Sounds whistle and displays signals	4	1

TABLE 2 (Cont)

GOAL III:

Objective A – Train crew in towboat-barge array control

TASK NO	TASK STATEMENT	FREQ	DUR
1	Interviews and evaluates new personnel	1	3
2	Conducts indoctrination tour of towboat and barges	1	4
3	Maintains standard reference information	1	4
4	Provides on-the-job training	5	5

Objective B – Evaluate trainee's knowledge and performance

TASK NO	TASK STATEMENT	FREQ	DUR
1	Observes trainee and discusses performance	5	4
2	Discusses problems with trainee	1	3

Objective C – Maintain required records

TASK NO	TASK STATEMENT	FREQ	DUR
1	Records required information		1

LEGEND:

FREQUENCY SCALE

1 – Performed once or less per 6-hour watch
2 – Performed once per hour
3 – Performed once every 5 to 10 minutes
4 – Performed once every minute or less
5 – Performed continuously

DURATION SCALES

1 – 15 seconds in length
2 – 1 to 5 minutes in length
3 – 10 to 30 minutes in length
4 – 1 to 2 hours in length
5 – Ongoing

NOTE: Blank in Frequency column = task performed as required.

would be meaningless. For example, in Towboat Goals II and III, the task "Studies bridges and bridge supports" occurs only when such structures are present. The frequency of performance varies directly with each specific waterway, or actually with particular sections of the waterway. The same is true of the task "Studies canal locks" in the same goals. The intentional grounding of the towboat-barge array occurs when the pilot must wait for traffic ahead to clear, or for a lock to open. Again, such grounding action is necessitated only by the simultaneous occurrence of several independent events; an estimated average frequency of such events was not considered valid. In each of these cases, however, the duration is generally standard, once the event occurs. Therefore, a duration estimate is recorded in the table.

Another comment is in order about the towboat tasks (Goals I, II, and III) which involve the use of radar, the fathometer, and the collision avoidance system. These pieces of equipment are not used routinely during daytime operations, but they are employed extensively during reduced visibility, i.e., at night or in fog, at which time the frequency and duration ratings would become 5 and 5.

Finally, a clarification is required for the ratings developed for tasks involving the taking of visual ranges and bearings to determine position of both tankers and towboats (in Tanker Goals III and IV, and Towboat Goal II). During the evolutions of maneuvering into/away from berth, and through restricted waters, the equipment specified in the task statement, such as alidade, pelorus, and sextant, are generally used only when "seaman's eye" is felt to be inadequate. The frequency and duration stated in the tables reflect the "seaman's eye" method. The use of navigational equipment would change the frequency to 3 and the duration to 1.

Graphic representation of the frequency and duration estimates is provided in Figure 9. Only tasks common to berthing/unberthing, navigation in restricted waters, and open sea navigation (for tankers only) are shown. The graphic display covers both tankers or towboats except that, for the latter, navigation on the open sea is not appropriate, and the tasks labeled "ELEC-RANGE/BRNG" and "NAVIGATION ORDERS" do not occur.

In Figure 9, the frequency and duration pattern for three different scenarios is shown: berthing/unberthing, navigation in restricted waters, navigation in open sea. Within each of these scenarios, three different operating conditions are included:

1. Maintaining designated track and speed, modifying as required by conditions (in order to avoid rammings and groundings).

2. Identifying and responding to potentially hazardous conditions (in order to avoid collisions, rammings, and groundings), while simultaneously maintaining position.

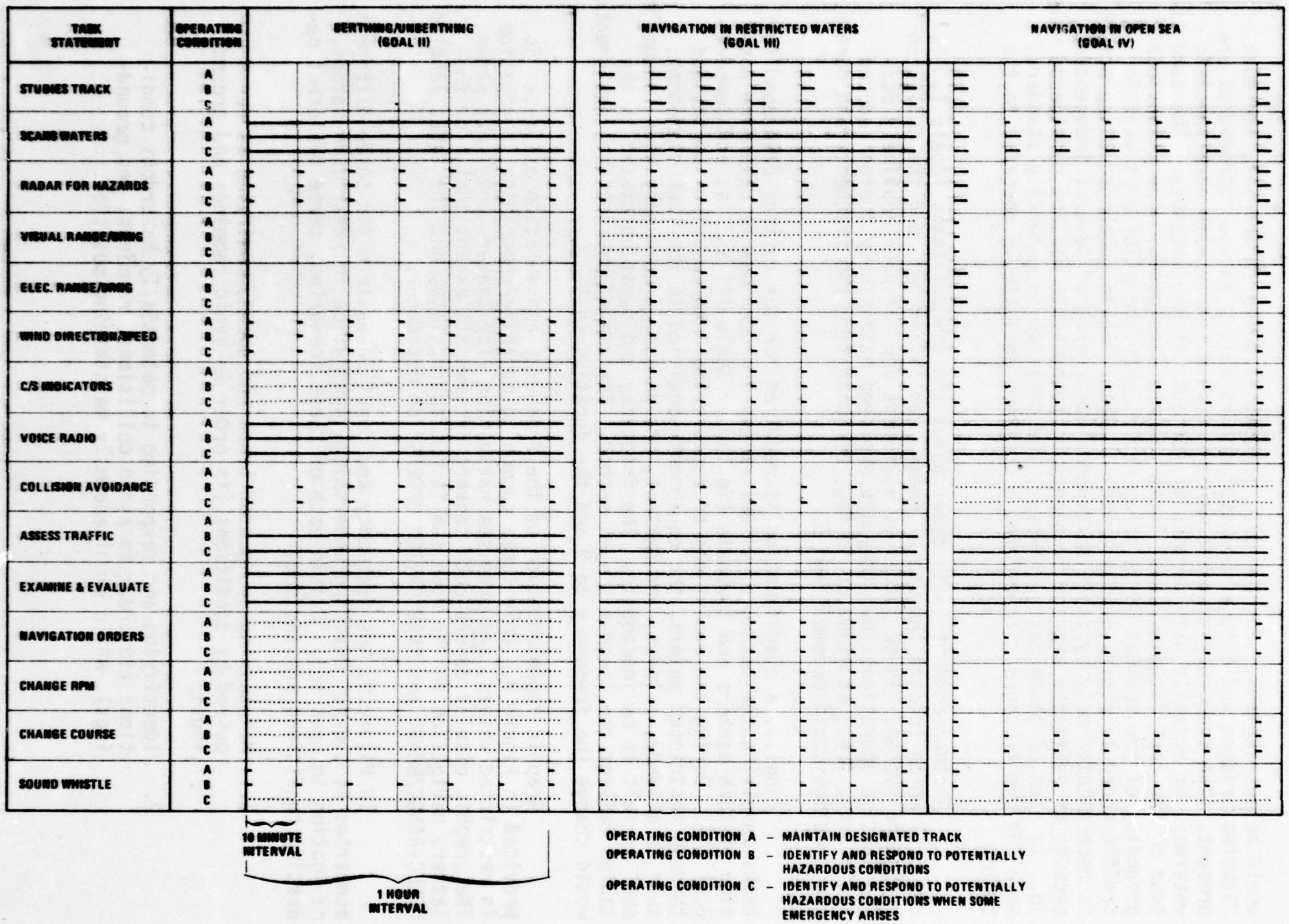


FIGURE 9. GRAPHIC REPRESENTATION OF FREQUENCY AND TIME DURATION RANGES FOR TANKERS/FREIGHTERS IN THREE SCENARIOS

3. Identifying and responding to potentially hazardous conditions (in order to avoid collisions, rammings, and groundings), while simultaneously maintaining position when some emergency arises.

The time period under each operating environment is one hour, divided into ten-minute intervals. This period is not intended to be representative of any specific time span of a bridge watch, or to show task flow or interfacing. It is simply a mechanism to display and compare frequency and duration of tasks during a typical one-hour period of a four- or six-hour watch. In order to distinguish between those tasks which occur once an hour from those which occur every four (or six) hours, the three-minute beginning of the following watch is included.

Going in the horizontal direction, one can see for each task listed the change (or lack of change) of that task performed under berthing/unberthing conditions, while navigating in restricted waters, or while navigating on the open sea. In the vertical direction, one can compare the frequency and duration of that task as it is performed under a variety of operating conditions.

The most apparent observation is that, in general, the pace of activity increases most for the condition of restricted water navigation, and then for the berthing/unberthing situation. This is commonly known, but Figure 9 graphically emphasizes this point. Since the pace of activity does increase, it can be assumed that omitted or poorly performed tasks will be felt more quickly and have more of an impact at those times. Also, while the omission may be detected more quickly or readily, there is less time to correct it. It seems highly probable, therefore, that system degradation would occur more readily. Thus it would appear desirable in future research to focus on maneuvering in the restricted waters and berthing/unberthing scenarios.

Another observation seen from Figure 9 is the continuous performance of two tasks regardless of scenario or operating conditions: "VOICE RADIO" and "EXAMINE AND EVALUATE." "VOICE RADIO" involves continuous aural alertness to incoming communications. "EXAMINE AND EVALUATE" requires continuous visual and aural alertness to updated data inputs and the synthesis of these inputs to formulate logical and practical navigation decisions. This task is going on all the time and represents the heart of vessel control decision-making capabilities. The nature of this task is discussed in more detail in the following section entitled "Lack of Visibility of Key Tasks."

While Figure 9 does not purport to document task flow or interface, as stated earlier, it does serve to indicate the variety of actions that may have to be attended to at one time. Many of the tasks the figure includes are known to be performed concurrently. For example, in addition to scanning the waters, listening for radio communications, assessing traffic in the vicinity, and generally examining and evaluating the situation (which must be done on a continuous basis), the person in charge of vessel control must also be attentive to course and speed indicators (C/S indicators) and may have to translate this information immediately into navigation orders.

Attention to many visual and aural inputs at once appears to be a common characteristic of the overall job of vessel control personnel.

On towboats, only one person performs all the stated navigation tasks. On tankers, most of the tasks (with the exception of actual changes in speed and course) are usually performed by one person. This means that, for the most part, a large quantity of data must be kept in mind during any one period of time. This may become particularly burdensome when the pace of activity increases, as is the case in tight maneuvering situations.

Figure 9 can be studied at great length to gain insight into the nature of individual tasks and/or the way in which an individual task compares in frequency, duration, and overlap with other tasks which are performed consecutively or in sequence with the task in question. A figure such as this provides the first step towards an initial, rudimentary investigation of issues of task overload (underload), and ultimately, touches on the issues of stress, boredom, fatigue, overwork, etc.—issues important to the understanding of the safety aspects of any work situation.

Lack of "Visibility" of Key Tasks

One of the characteristics of the vessel control system, in terms of the quality of the man-machine interaction, is that this system is not "technologized" to the point that every action made by the man can be seen. That is, most of the time the man does not merely push buttons or perform other highly visible tasks. Much goes on in the man's head that cannot be seen (particularly for the person in charge). This makes it difficult to capture all the tasks that are actually occurring at any one point in time. It also makes it difficult to write any kind of operating procedures or to train personnel in the specifics of the job. The best one can do is write procedures at a trivial level, e.g., take fix every 5 minutes, and/or to train people in the relatively simple, highly visible tasks. After that, one must hope that the man gains "experience," "know-how," or a "feel" for the job, i.e., learns the invisible, mental tasks, that will make him a good mariner. Needless to say, this leads to a major problem when addressing the topic of safety, since it is difficult to "make safer" tasks which are not visible. This observation, among others, led the ORI study team to develop a schema of the flow of information of bridge control operations and decision-making functions, which is discussed in detail in the following section.

Flow of Information in Vessel Control

As the task analysis proceeded, a pattern emerged among the statements related to the type of action being performed. The statements appear to fall into three categories. The first category deals with actions involving information gathering, such as monitoring communications, scanning radar, reading dials, etc. The second category is related to mental, decision-making tasks. The third category covers output-oriented tasks in which actions are executed, e.g., turns helm, adjusts speed, relays orders, etc. Thus, the overall flow of information begins with information-gathering or data input tasks, moves to data synthesis tasks, and ends with action-oriented, output tasks. Of course,

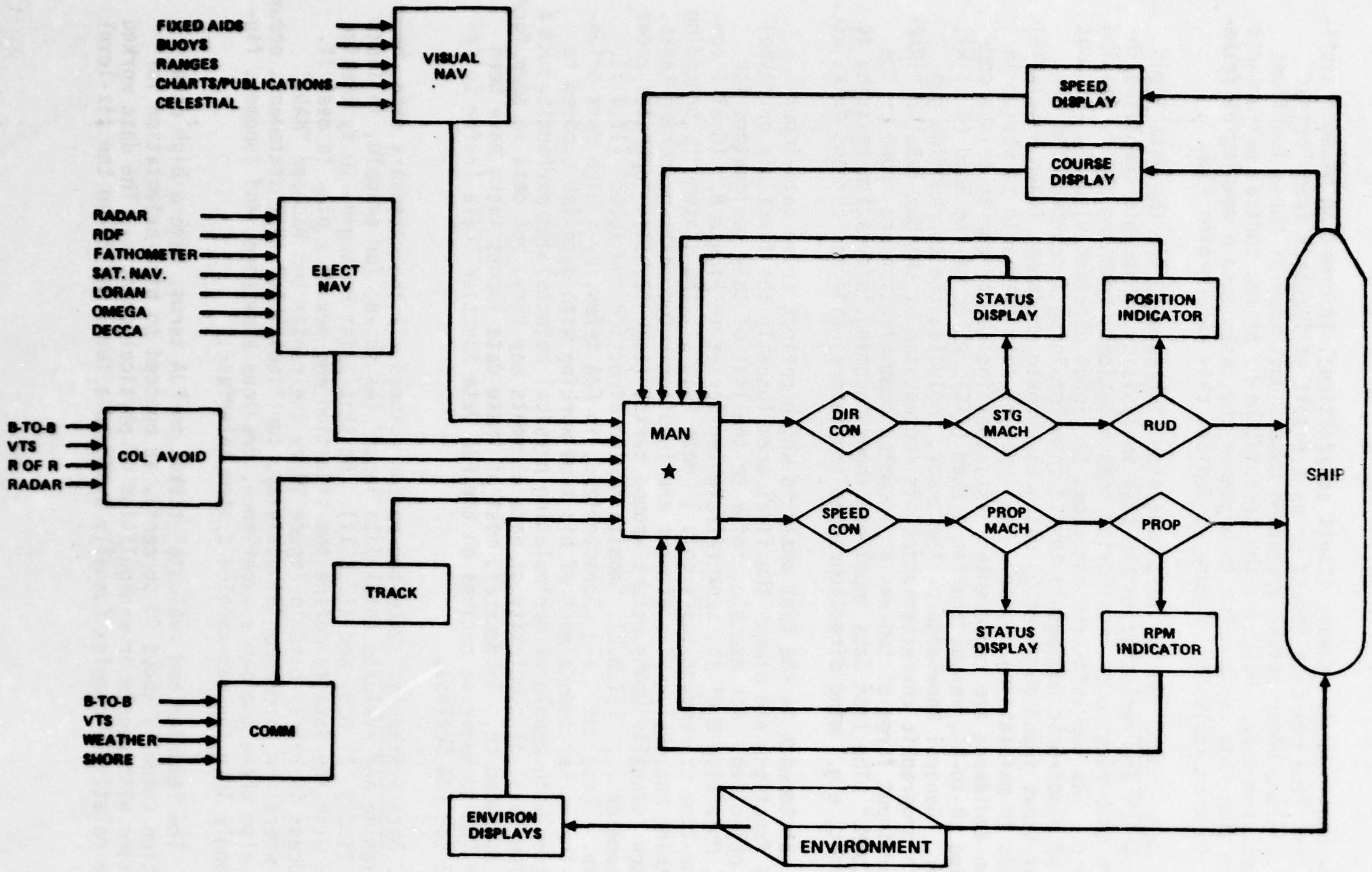
this flow continuously repeats itself as additional information becomes available (either from new data inputs or as a result of feedback from "output" actions). Also, under actual operating conditions, many of these functions occur simultaneously. However, the description of bridge control performance in information-flow terms helps to organize the tasks into a meaningful framework for further analysis. Figure 10 depicts this information flow.

Data Input. On the left-hand side of Figure 10 are the data input sources, which are reflected in the task analysis by statements involving information gathering, e.g., monitoring communications, scanning radar, reading dials, etc. The top left-hand box shows the input obtained visually (without the aid of electronic equipment) to aid in maintaining a course. The next lower box shows input obtained by using electronic equipment (when available) which aids in maintaining course. The types of data available to assist in collision avoidance are represented next; they include bridge-to-bridge communication (B-to-B), vessel traffic system (VTS), Rules of the Road (R of R), and radar. General knowledge of the track, including the surrounding geographic/hydrographic characteristics, is represented by the box labeled "TRACK." The major input forms of two-way or incoming communication are shown by the label "COMM." The last data input box shows incoming information relating to environment, e.g., wind direction/speed indicators, tide and current data, etc.

Statements in the task analysis which reflect these data-input-oriented functions are always the first ones (usually the first six or seven) of each objective. For example, refer to the list of task designators for Goal II, Objective B of the tanker/freighter series in Figure 8. (Goal I contains one-time pre-voyage tasks only.) Note that all the statements preceding the "Examine and evaluate" statement are input-oriented, data-gathering tasks. The person "visually scans waters around berth" (Task II.B.1), "operates radar and fathometer ..." (II.B.2), "monitors wind direction and speed" (II.B.3), and so on. These tasks are characterized, in FJA terms, by a high data orientation—the worker spends most of his time working with data (as opposed to interacting with people or manipulating physical objects) when performing such a task. The level of complexity of data elements may vary, but data in some form must be attended to. In general, most of these data inputs tasks have been assigned low to moderate ratings on the FJA Data Function Scale (refer to Appendix E for FJA Scales).

Data Synthesis. Once the person gathers all the necessary data, he must "examine and evaluate total data input" (as shown, for example, in Tasks II.B.7, II.C.9, II.D.9, and III.B.11). At this point he begins to synthesize and work with the data to define the situation and devise a plan to meet it. This process is represented in Figure 10 by the center box labeled "MAN." This is where the unseen mental activity, the "invisible" task statements occur. This is also where the man's experience, previous knowledge, and judgment figure strongly into the man-machine system interface.

The "examine and evaluate" tasks, in FJA terms, have a high data orientation (usually about 90 percent), as opposed to high orientation for interaction with people or manipulation of physical objects. The data worked with are relatively complex (usually assigned a level of "5" on the six-level



★ INTERPRETATIONS OF PRESENT CONDITIONS; CONCEPTS OF POSSIBLE FUTURE CONDITIONS, ACTION ALTERNATIVES AND RESULTS.

FIGURE 10. FLOW OF INFORMATION FOR VESSEL CONTROL

level FJA Data Function Scale; see Appendix E). In addition, the person has much leeway or discretion in the performance since no standardized pre-written procedures are available. These tasks are usually rated at "5" on the eight-level FJA Scale of Worker Instructions (degree of discretion). FJA also shows that good reasoning skills are required, "the ability to deal with theory vs practice, abstract vs concrete, and many vs few variables." In short, FJA indicates that the examine and evaluate tasks are the most difficult tasks of vessel control. They are the most difficult of the data-oriented tasks, requiring the highest level of functioning in relation to data, as defined by the FJA scales. In addition, they require, a higher level of functioning in their dimension than the people- and things-oriented tasks require relative to the range of scale values in those dimensions. (The training and supervisory tasks, pp. F-180 through F-183, are notable exceptions; they are rated relatively high on the People Function Scale as well as the Data Function Scale.)

It is necessary, however, to go beyond the definitions of the FJA Scales to express the nature of the examine and evaluate tasks. In the Performance Standards and Training Content specifications we have used phrases such as "anticipates any and all possibilities which may arise," "continually maintains mental alertness," "maintains sense of proportion among input data and various action options as situation changes," "knowledge of own and other ship's hydrodynamic characteristics as they may be affected by prevailing environmental conditions at the particular locale and the seasonal variations ... through the range of expected values." These standards and requirements, which are acknowledged as real by bridge personnel, indicate that the "total data input" exceeds that which the person in charge receives from external sources in present time. The total includes stored knowledge and what we might call imaginative input which he creates based on the present data and stored knowledge, especially the knowledge generated by experience. It appears that the process of examining and evaluating involves virtually instantaneous creation of one or more intermediate data sets that might be described as mental maps of the situation, the contingencies that could arise, the alternatives for action and their possible consequences. We have no proof that this is true, beyond the seagoing experience of study team members and with interviews with bridge personnel. (They do not usually describe the phenomenon with such fancy words, but rather speak of seaman's eye, experience, a "sixth sense," etc.) The occurrence of a mental mapping process does not, however, seem to be in much dispute. The skills and capacities that may be involved in the process are not well defined; they would appear to be important and to warrant attention in future studies of vessel control.

No training program of which we are aware purports to give its students, directly, the skills and knowledge necessary to perform the examine and evaluate tasks of vessel control successfully. Experience—simulated and/or real—is conceded to be the best and probably only teacher. That is the reason for the lengthy apprenticeships of pilots, required by their own associations.

Moreover, other factors may interfere with even the most experienced individual's performance. It was noted above that a continuing state of alterness is required—"defensive awareness." Alertness can be affected by physical and emotional well-being and of course, by transitory distractions.

One other point needs to be made concerning the "examine and evaluate" tasks. Their results are judgments that determine the safety of vessel control more directly than the results of any other task performed in vessel control. In a study of vessel collision reports from fiscal years 1964 through 1974, it was estimated that judgment errors (by the person in charge of vessel control) contributed to approximately 40 to 50 percent of the collisions that occurred (ORI, 1975). Judgment error was identified as a factor far more frequently than "other human factors." Table 3, reprinted from that earlier study, provides a summary of the findings concerning the relative incidence of different types of human error as identified in the collision reports. Although the collision reports did not so indicate, it could be that faulty information was the source of the faulty judgment in some cases. Regardless of the source, however, the impact was on the decision. In addition, the decision-maker has the responsibility, when he "examines and evaluates," to recognize erroneous or insufficient information (whether he obtains it himself, or someone else provides it) and to adjust for it by whatever means he can in the time available. That may be asking too much in some instances, but it is an accepted fact of maritime life.

Thus for a number of reasons, as explained above, it is suggested that the "data synthesis" or "examine and evaluate" tasks are the most critical tasks of vessel control:

- The FJA Scale ratings (Appendix F) indicate that these are the most difficult tasks performed on the bridge; it appears reasonable, on that basis alone, that they may be more susceptible to error than other tasks.

- The skills and capacities involved are not yet clearly identified and certainly are not well understood; currently available training cannot address them directly.

- Sustained alertness is a condition of successful performance of these tasks (see Task Statements II.B.7, II.C.9, II.D.9, III.B.11, in Appendix F, for example; see also Table 2 and Figure 9). Alertness may be affected by varying personal and environmental conditions that are not readily predicted.

- Failure in any other task of vessel control may impinge upon these tasks (as may be seen by reading the task statements for Objectives II, III, or IV, and relating them to Figure 10).

- "Judgment error" by the vessel control decision-maker has been identified as a causal factor in 40 to 50 percent of collisions, according to casualty reports from the 10-year period 1964 through fiscal year 1974.

TABLE 3

HUMAN FACTORS FINDINGS:
JUDGMENT ERRORS AND OTHER HUMAN ERRORS
(Reprinted from ORI, 1975)

	Thirty Percent Sample	One Vessel Over 10,000 Tons
Judgment errors	43.8%	50.0%
Position, course of own vessel in channel	4.4%	7.6%
Position, course of other vessel in channel	7.5%	7.6%
Relation in long-range crossing	2.1%	5.6%
Intentions of other vessels	9.3%	7.6%
Maneuver not feasible	7.5%	6.6%
Effects of wind or current	6.2%	5.6%
Illogical maneuver	5.7%	7.1%
Passed closer than necessary	4.8%	3.5%
Maneuvered closer to band than necessary	3.5%	1.0%
Other judgment errors	2.1%	3.5%
Other human factors		
Navigation error	0.6%	1.0%
Poorly given helm or engine order	0.2%	0.5%
Poorly executed helm or engine order	0.4%	1.0%
Poor maneuvering	6.0%	3.0%
Inexperience and lack of familiarity with waterway	0.4%	2.5%
Did not hear or misheard whistle signal	3.9%	1.5%
Poor use of radar information	5.4%	7.6%
Inattention	6.3%	8.0%
Misinterpretation of rules of the road	0.6%	0.0%
Problems with using bridge-to-bridge radiotelephone	6.9%	9.1%

The frequency with which judgment error was reported by far exceeds the frequency with which any other human factor was reported (see Table 3).

Action Output. Moving from the data synthesis function ("MAN") to the right side of Figure 10, one sees the output, result-oriented tasks. These functions are the actions taken as a result of the data synthesis or "examine and evaluate" tasks mentioned above. In Goal II, Objective B, the tasks which come after the "examine and evaluate" task reflect the output or result-oriented tasks, e.g., "conveys navigation orders to other personnel" (II.B.8), "adjusts ship's RPM," (II.B.9), "turns ship's helm," (II.B.10), etc. These tasks tend to be more things- and/or people-oriented and have much lower reasoning and worker discretion ratings than the data synthesis tasks.

When these tasks are executed, the vessel responds in a particular way, as indicated by its movement, which registers on various indicators or displays that serve as feedback to provide more input data. Feedback is also provided from the various indicators and displays associated with the steering machine ("STG MACH") and propulsion machinery ("PROP MACH"), which give the status and performance responses of those systems. The environmental conditions influencing the movement of the vessel appear as feedback through the speed and course displays and through other characteristics known about the specific vessel. Thus, an information flow loop is created, consisting of initial inputs, evaluation of inputs, action outputs, and feedback from actions which become inputs.

Implications of the Analysis of Vessel Control Task Data from an Information System Perspective

By viewing the vessel control tasks from this perspective, it is possible to begin to pinpoint areas of future investigation. For example, the following questions might be asked:

- If numerous sources of data are needed as input to operate a vessel successfully, are all necessary data available? are they available in the appropriate format?
- Is training available to orient and familiarize personnel with sources of input data?
- Are sources of input data standardized enough to aid in transfer of training from the school to the work setting? from one work setting to another?
- Are personnel being selected whose characteristics include the ability to absorb, analyze and synthesize various kinds of data input?
- If "invisible" data synthesis ("examine and evaluate") tasks commonly figure into the normal work flow of

vessel control, how can we find out more about the characteristics of these tasks? and select personnel who demonstrate these abilities?

- Can personnel be trained to better perform data input or data synthesis tasks?

RECOMMENDATIONS BASED ON THE TASK ANALYSIS

The following recommendations fall into two major categories. The first category of recommendations relates to the need for accurate, complete data and the existence of the adequate, appropriate data sources. The discussion in the preceding section of this report concerning the flow of information in vessel control emphasized the high degree of data-oriented tasks and the variety of data sources to which the worker must attend. Specific recommendations are made to improve data inputs to the worker.

The second category of recommendations relates to data synthesis characteristics of the vessel control job. This topic was also discussed in the preceding section in relation to the information flow schema. Specific recommendations are made to try to improve the probability that the person performing vessel control functions will have the best opportunity and available aids to choose and/or formulate the best possible navigational alternative under any given set of circumstances.

The recommendations are stated, the reasoning behind them described and their feasibility assessed. The question of who would have responsibility for implementing the recommendations is addressed. After all recommendations have been presented, benefits and means of evaluation are discussed.

Recommendations Relating to Data Input and Data Sources

1. More standardization of basic equipment characteristics and minimum performance capabilities should be considered to promote transfer of training and minimize unreasonable adaptive demands on the worker.

Rationale. The task analysis results demonstrate that many of the tasks involve operating or manipulating a variety of equipment to obtain information about the environment and vessel status, and/or using such information in making vessel control decisions. (In addition, of course, the actual maneuvers are effected by equipment.) To assure that the available equipment does in fact aid vessel control, it is necessary (a) to assure that the devices themselves meet basic performance standards and (b) that vessel personnel know how to use the devices.

No minimal performance standards for equipment now exist. It is known, for example, that the bearing resolution of some radars may vary as much as $\pm$ 10 degrees. With that variance, the full potential of radar as a navigational aid is not realized.

Broadening the issue of equipment performance standards, there is also considerable variation in equipment onboard different vessels and between equipment used in shoreside training and that used in service. The variation may make it difficult for personnel to transfer shoreside training to operations tasks and to adapt easily to different vessels.

For example, the procedures used to assess risk of collision based on input from a gyroscopically stabilized radar cannot be employed with an unstabilized radar. Without getting into the merits of stabilization, personnel certified as radar operators on the basis of training on one type may have to work with the other type.

LORAN A and LORAN C provide another example. LORAN C will predominate in the near future, and personnel trained and experienced on LORAN A will have to use it. Conversely, it is not improbable that personnel trained and experienced on LORAN C will have to use LORAN A at some time. The transfer would not be automatic and would involve a reduction in the amount of information available.

The variation in bridge control of the main propulsion system may also be cited as an example. The engine order telegraph is still widely used—an indirect control system through communications. Direct control systems on newer vessels may allow the operator to set rpm specifically or they they initiate pre-set rpm when the operator selects a speed category such as Full Ahead. In addition, direct control systems may be flush mounted and operated by turning a dial like the hands of a clock or they may have a fore and aft, throttle design. These are perhaps not big issues, but such differences are likely to be disconcerting, at least temporarily.

Bow thrusters provide another example. With some systems the vessel moves left when the thruster control is pulled to the right; others are designed so that the direction of movement of the operator and vessel correspond.

The examples given are not intended as a definitive inventory of types of equipment that should be standardized. The examples are included to illustrate the point that major items of navigational equipment may vary in very basic characteristics.

The airlines industry avoids problems that equipment variation may introduce by standardizing equipment and maintaining high correspondence between type and arrangement of training and actual equipment. This provides high correlation between specific training content and actual task performed and, also, between functional training (general "know-how," background training) and specific training (related to specific setting or equipment). These two categories of training are clearly shown on the FJA task statement sheets, thus emphasizing the necessity for both general and specific knowledge and the importance of transfer from one to the other.

While flexibility in equipment design is desirable in a number of respects, as equipment becomes more complex the advantages of some basic congruities would appear to outweigh the advantages of total flexibility.

The development of basic standards should be beneficial to all bridge personnel, and particularly beneficial to pilots who must handle many different types and classes of ships under the most demanding of maneuvering conditions.

We stress that it is not our intention to advocate one equipment design or manufacture over another. Nor are we recommending a standardized bridge. Task analysis alone does not provide an adequate basis for evaluating equipments and bridge designs. Moreover, rigid standardization does not appear necessary or economically justifiable. It does appear both desirable and possible for the industry to agree upon and adhere to basic minimum standards of equipment design and operating conditions. It also appears both desirable and possible to find a way of assuring that training and task requirements are compatible and that changes in service do not result in serious skill deficiencies and stress on personnel, even temporarily. It is believed that these are desirable directions for developments in the industry.

Feasibility and Locus of Responsibility. It should be possible to formulate and institute basic equipment performance standards of the kind recommended without great difficulty. It will be necessary for various organizations associated with the industry to participate in discussion of specific changes and a schedule for implementation. A cycle for review and updating of standards is also recommended.

Owners/operators, trainers, bridge personnel and their union representatives, the regulatory agencies and manufacturers should participate in developing the standards, involving the research community as needed. It might be necessary for the training organizations to make some adjustments in their curricula as well as for operators to make some equipment adjustments. It may be desirable to accommodate certain equipment differences by means of onboard indoctrination programs. It would be the Coast Guard's responsibility to assure that the basic equipment performance standards and any associated personnel requirements are fairly applied and enforced. The latter could be done through existing programs such as the vessel inspection and personnel qualification programs.

Assessment of Expected Benefits. It is believed that implementation of basic equipment performance standards will promote

- greater reliability in task performance related to (a) equipment capabilities and (b) equipment utilization factors.

It will be possible to state benefits more specifically when standards have been developed. Methods of assessment may then also be more specifically formulated. Methods of assessment are outlined here, however, in relation to the general statement of benefits given above.

Three methods are suggested. Tradeoffs of expected validity of results and of costs would have to be evaluated. More than one method might be used, depending on the extent of debate over the merits of proposed actions.

Again, when particular standards have been proposed, methods of assessment should be considered in detail.

First, it may be useful to pretest proposed standards by implementing them on designated (voluntary) experimental vessels. The purpose would be to obtain an operational evaluation before implementation on a large scale. There would be difficulties to work out, such as who pays for experimental modifications, willingness of owners/operators to volunteer, the effects of experimental observations, and the effects of possible interests of owners/operators (and operating personnel as well) in avoiding changes.

Pretests might also be accomplished by simulation. Simulation would allow greater control over extraneous variables, but would have less fidelity to actual operations.

In either case, a before and after design might be employed (i.e., perform tests under existing conditions and then comparison tests introducing modifications). Running two sets of tests would take somewhat more time and cost somewhat more, but would provide a more solid basis for evaluating proposed modifications.

Another approach to assessment of benefits would be to survey operating personnel. A pre- and post-implementation design would be desirable. The information to be sought would be, essentially,

- What equipment is available?
- Can you use it? (If not, why; limitations if any)
- Do you use it? (If not, why)

and (after implementation)

- How would you evaluate the changes that have been introduced?

Sampling should reflect vessel classes and operating areas. Other sampling parameters may be desirable. The sample should be designed with care to assure insofar as possible that differences in service are understood.

It is probable that some investigation of equipment availability, performance, and utilization would be made as a basis for development of specific standards. A procedure for checking compliance with any modifications is also likely to be introduced. Field work for those purposes could be planned so as to provide for the assessment of expected benefits.

The third method of assessment would be to look for changes in casualty patterns that might be attributable to modifications resulting from this recommendation. ORI (1975) analyzed casualty data to assess the effectiveness of bridge-to-bridge radiotelephone and collision avoidance radar systems (CARS). The radiotelephone analysis was purely retrospective. The CARS analysis examined casualty histories to determine whether occurrences could have been prevented by CARS.

Casualty-based assessment employing existing casualty reports requires careful design to ensure reliability. In addition, the limitations of the reports constrain the analysis severely. It may be possible to modify casualty investigation guidelines to assure that the kinds of information needed for the subject assessment are available. This would have to be done promptly so that casualties that occur during development of specific standards may be documented in a way that will make identification of casualty-related circumstances and their relationships easier than it is now. The point being made here is that pre-implementation baseline data are required for assessment of any system change. The present casualty reports do not provide optimal information and might be improved.

2. Reliable data are needed on current speed and direction and the interaction of those variables with others (such as channel configuration and placement of natural and man-made features, vessel horsepower and displacement) so that vessel control requirements and limitations may be better understood.

Reationale. The only available information about currents comes from tidal and current tables and individual familiarity with the waterway. Until familiarity develops through experience, the person in charge has little basis for anticipating and deciding how best to handle local current effects. As significant as this factor is to vessel handling, particularly on the rivers, and in harbors and other dense traffic areas where variable set and drift are experienced, reliable data on currents and their effects in relation to other variables should certainly be helpful.

The recommendation concerning current data applies to both deep draft vessels and towboats. The recommendation is interpreted somewhat differently for the two types.

Towboat captains and pilots tend to work regularly, for relatively long periods of time, on one route. They become thoroughly familiar with the waterway characteristics. Thus they have relatively accurate, detailed knowledge of current characteristics associated with river stage in their areas of operation. In addition, the towboat personnel tend to remain with the same vessel and are thoroughly familiar with its response characteristics under seasonally varying conditions and with varying tow composition.

The masters and mates of deep draft vessels typically do not have the opportunities for sustained ship handling experience in a particular area so as to develop detailed personal knowledge of conditions. The pilots who handle deep draft vessels in port areas and certain restricted segments are familiar with local conditions but may have larger areas of water in which to operate. They must also quickly adjust to the handling characteristics of different ships and to different crews.

It is believed that provision of advance information on current conditions (velocity, direction) would be helpful in the maneuvering of deep draft vessels. Towboat personnel tend to be relatively well informed about current conditions, but they too could benefit by more precise and reliably obtainable information.

It is within existing capabilities to provide this information; in fact it is done now at some locations. The procedure to install a current meter (available from a number of manufacturers including Raytheon Company, Lexington, Mass. and Acrison, Inc., Moonachie, N.J.) in the water on a fixed object such as a dock pier. Meter readouts are obtained by personnel at the site and communicated by radio to incoming ships. This practice is proposed for the port at Valdez, Alaska, a terminus of the Trans-Alaskan pipeline. It would appear within reach of present technological know-how, to develop a means of automatically retransmitting the current meter signal to approaching vessels equipped with receiver units. Developmental research would be necessary to make this possible, but, again, it does not appear to be beyond reach. Appropriate current meter locations would have to be studied, along with the costs of introducing the presently feasible procedure on a systematic, widespread basis. (These costs, at least for current readouts in port areas, should be small.) The feasibility time requirements, and costs of developing an automated system also require study. It is recommended that this be done.

With regard to the problems of river navigation in particular, something more is needed. It is recommended to pursue research to describe the interactive effects of current and other variables on towboat controllability.

The task analysis of towboat operations documents the many factors a river captain or pilot must take into account in order to maintain track or position and avoid collision, ramming, and unintentional grounding (see Appendix G, Goal II, Objective A, B, or C, pp. G-48 through G-102). The total set of interrelated factors is represented, for example, in Task Statements II.A.11 (p. G-58) and II.B.13 (p. G-77) and II.C.13 (p. G-96). The first cited statement might be called the base case; the second introduces an imminent navigational hazard; the third introduces a hazard not related directly to vessel control. The requirements in the three cases are similar. For example (from p. G-58), the person in charge must know the towboat's

- Hydrodynamic characteristics as they may be affected by particular barge array and prevailing environmental conditions at particular locale (including bank suction within locks and eddy currents around bridges), and the seasonal variations of those environmental conditions through the range of expected values

- Ancillary equipment and shoreside ancillary equipment provided in particular locale as they affect towboat-barge array hydrodynamics and as they may be affected by varying local environmental conditions.

The Task Statement shows that the individual must (among other things)

- Maintain sense of proportion among input data and various action options as the situation changes or progresses

- Make (vessel control) decisions in timely manner commensurate with situation.

There is no training that addresses those requirements explicitly. River captains and pilots and the operating company personnel say that the necessary skills develop through experience. There is a mystique about the skills involved, as well there might be. An observer of towboat maneuvering begins to realize what the task statements represent. The following excerpt from another ORI report gives a sense of the scenario in which these tasks are performed (Dayton, 1976):

> Rounding and coming out of the bend is the most critical procedure [during high water]. The tow must hold the inside bend and as a consequence does not align with the current flow. This ...[creates] a situation whereby the stern of the tow is in a stronger current field than the bow plus the direction of the current forces on the stern tend to push the stern toward mid-river and to rotate the tow counterclockwise. If the operator does not react in time to counter this movement or if there is not sufficient restoring power to counteract it, the tow will rotate until broadside to the current flow and float down on the bridge completely out of control ... This rotation in the current is called being out-of-shape. The brief commentary in the accident reports such as "misjudged effects of current on tow" means that he got out-of-shape in the bend a mile above the bridge and could not recover in time to make the bridge passage safely.

The study just quoted dealt with bridge collisions. It concluded that the primary cause is lack of control under extreme conditions of current, which are encountered four or five months a year, and of wind, which occur more randomly.

Thus it is recommended that current effects on towboat control be studied and demonstrated experimentally with the minimum objective of establising probabilities of successful passage under a range of typical conditions. It is believed that this can be done by mathematical modeling and/or by computer modeling in a relatively short period of time. A longer-term effort to develop a real-time simulation of towboat control problems might be considered.

Feasibility and Locus of Responsibility. The time required for development of a viable current sensor cannot be predicted with confidence at this time. Still it seems worthwhile to continue pursuing this goal. The Coast Guard, the Maritime Administration, other government agencies, and other organizations concerned with the safety and efficiency of maritime operations would be needed to help sustain the effort through their interest and financial support. The research community obviously would be involved. Equipment manufacturers would have an interest. Vessel owners and operators would benefit by the availability of such a device. Thus responsibility for the development effort should be shared.

It appears probable that the Coast Guard would have to take the lead in initiating the recommended towboat control research. Responsibility for

the development of a real-time simulation, however, should be shared in by other organizations as well, including the National River Academy, and the river pilots' associations, as well as government agencies outside the Coast Guard and the research community.

Assessment of Expected Benefits. The benefits of an onboard current sensing device may be assessed in the following ways:

- Through the opinions of vessel handling personnel as to whether the device is useful
- Through observations of the actual use of the device
- Through analysis of casualty trends before and after installation of the device on a suitably large scale.

Operational tests would provide an opportunity to apply the first two types of assessment, limited by the scope of the test effort. For any formal effort designed specifically for benefit assessment, it is recommended that a sample of port areas or other areas in which currents are relatively strong and variable be selected; a range of typical conditions of traffic patterns and physical boundaries, as well as water characteristics ideally should be represented. Companies with ships operating in those areas may be asked to participate in a trial of the device(s) for the purpose of benefit assessment. An attempt should be made to involve a range of ship types, sizes (under a threshold of significant susceptibility to current effects), and perhaps hydrodynamic characteristics. It would also be desirable to assure appropriate numbers of personnel as characterized by educational background, age group (two categories should be sufficient), and/or years of relatively continuous active service. Such categorizations would allow a relatively sophisticated analysis in which hypothesized intervening variables may be held constant. That kind of analysis may not be considered necessary, depending on the costs of implementing the device, in relation to the investment in its development, the costs of assessment, and the results of pretests of operational effectiveness (including the reactions of personnel on pretest ships), and the general receptivity of owners/operators to introduction of a current sensing device.

It should be possible to perform an analysis of casualty trends in conjunction with a trial implementation as just described, provided that (a) the trial involved sufficient numbers of vessels and (b) the trial was long enough.

It should be noted that participation in an experiment inevitably affects personnel performance (usually positively). Thus it probably would be preferable to conduct analysis of casualty trends after full-scale implementation whether that occurred on the basis of the results of pretests of operational effectiveness or after a partial implementation trial period. Baseline observations from data on casualties occurring for a period prior to implementation would be required. With this in mind, improvements in the casualty report forms and guidelines should be made as soon as possible. (Some suggestions of additional elements of information that would be desirable are made later in this report. However, revisions in the casualty investigation guidelines and report formats should not be made ad hoc but rather on the

bases of a deliberate study of requirements.) An adaptation of Quasi-Experimental Methodology for analysis of casualty records was developed by ORI for evaluation of other types of navigational aids, as discussed in relation to Recommendation 1. That methodology would seem to be applicable here.

Several types of uses might be made of the results of the recommended study of current interaction effects on vessel controllability. The possibilities include:

- Furnishing results to owners/operators, pointing up the implications of results for safety and operating costs, and suggesting such guidelines for operating practice as may be appropriate.

- Introduction of study findings and model illustrations as training materials, through the owners/operators and/or the National River Academy.

- Improvement or establishment of vessel traffic control system requirements. (It is noted that constraints on traffic movement would have to be evaluated very carefully because of their potential impact on the operating companies.)

The benefit of such actions could be assessed in several ways. As a preliminary, it is noted that computer model test results including appropriate sensitivity analyses would provide for evaluation of the theoretical basis for any proposed actions. In addition, it might be desirable to perform real-time simulation experiments to test the theoretical results (say, for example, probabilities of ramming or grounding) under conditions closer to actual operating conditions, prior to final recommendation or implementation of potential actions. Benefits of implemented actions (whether on a partial or full scale) might be assessed on the basis of

- Personnel opinion of, say, training innovations

- Personnel knowledgeability of current factors before and after exposure to study results

- Effects of study information provided to owners/operators on company policy and practice

- Before-after analysis of casualty patterns.

Details of assessment design can be addressed more meaningfully after specific action alternatives have been formulated.

3. The system of aids to navigation should be assessed with particular attention to needs during navigation at night, under conditions of poor visibility, and in segments in which maneuvering requirements are severe.

Rationale. The task analysis documents the reliance of the vessel handler on the system of aids to navigation. For example, there are 44 task statements for tankers under the goal to "Navigate through (maneuver in) restricted waters ..." (Goal III in Appendix F). Fifteen of those task statements, 34 percent, explicitly reference aids to navigation. The 15 are all information gathering tasks. (The other information gathering tasks do not directly and/or necessarily involve utilization of aids.) The "data synthesis" tasks, as previously discussed in detail, involve integration of information from aids to navigation with other information. The remaining tasks are those of enacting a navigational decision and thus indirectly rely on the system of aids. There are 34 task statements under the comparable towboat goal (Goal II, Appendix G) of which 15 (44 percent) specifically reference aids to navigation. The other comments made about the tanker statements apply.

The system of aids to navigation has evolved over a long time. Aids typically have been put in on the basis of requests from waterway users and on the basis of traffic and casualty history. It appears desirable to evaluate the need for existing aids, additional or alternative locations and types, and their visibility under the range of expected weather conditions and seasonal and diurnal variations in water level. This kind of evaluation would seem to be appropriate periodically, to keep pace with changes in traffic patterns and channel configurations. (Gynther, 1974, discusses system problems and directions for analysis.)

Although vessel operators rely upon the system of aids to navigation day and night, under all states of visibility, the need is greater at night and, especially, under poor conditions of visibility. At those times, it is more difficult to make use of cues provided by natural or man-made features of the environment.

Added lights on buoys should be considered to assist nighttime navigation. In addition, the use of radar transponders on major aids should be considered to increase radar fidelity. It is noted that bridge personnel interviewed during one observation trip made during this study felt that they would be helped significantly by a transponder on Dry Tortugas, a key reference point on the route from the Gulf Coast to the North Atlantic Coast through the Florida Straits.

A special problem exists with buoys, which tend to come off-station during periods of high water or may be knocked off by passing vessels. Conversations with towboat personnel and the observations made by the study team pointed up this problem and indicated that there may be long delays in repositioning buoys. With thousands of miles of navigable waters to cover, and thousands of aids to check, delays are not surprising.

Feasibility and Locus of Responsibility. It appears that this recommendation could be implemented through the Coast Guard's established program for positioning and maintenance of aids to navigation. However, caution would be required to assure that any proposed modifications to the present system would not overburden the capacities of the program. In fact, the modifications can and should be designed to reduce the present burden. It is not desirable to proliferate aids to navigation that cannot be maintained satisfactorily. As suggested above, it is probable that a good number of existing

aids are not utilized by significant numbers of vessels. However, once an aid is installed, it can be extremely difficult to get agreement from the variety of waterway users that it may be removed. Despite these difficulties, aids to navigation are so basic to vessel control that it seems essential to provide the best system possible.

To overcome the difficulties it may be possible (a) to introduce changes that would reduce the effort required for the Coast Guard to place, check, and maintain aids and (b) to devise methods of making and supporting decisions about needs for aids that would minimize dispute.

As an example of (a), bridges are marked now by buoys set alongside. The whole problem of off-station buoys in these locations could be eliminated if the bridges themselves were appropriately marked with reflective tape, lights, or both. Radar transponders on bridge supports could also be beneficial. The marking of bridge supports is treated as a separate recommendation, but the potential benefits of incorporating bridges into the system of aids to navigation seem clear. This would require cooperation between the Coast Guard and the Corps of Engineers for highway bridges and between the Coast Guard and the railroads for railroad bridges. Based on the comments of vessel personnel during our observation trips on inland waters, it is unlikely that there would be any objections to the removal of buoys at bridges in favor of suitably marking the bridges.

As another specific example of (a), it may be possible to draw upon the knowledge of vessel personnel working on the inland waters. Experienced masters and pilots who are thoroughly familiar with a route know when a buoy is off station. It is believed that they would be willing to report off-station and otherwise malfunctioning aids. It is also believed that appreciation and some official recognition would be sufficient incentives. (There were indications that reports of off-station buoys have in some instances been responded to as if they were harassment.) It may be possible to designate as reporters experienced personnel who customarily work over particular routes (provided some means were found to assure they would have no liability for unreported malfunctions).

Methods of making and supporting decisions about needs for aids (item (b) above) are treated subsequently, in discussion of how this recommendation might be implemented. First it seems appropriate to mention liability, another kind of Coast Guard program constraint.

It may also be desirable to assess the legislation concerning liability for off-station buoys and otherwise malfunctioning aids. It may be that the present law is counterproductive by making every aid a potential source of liability. Some means might be found of distributing the responsibility more reasonably. For example, good practice dictates that vessel position be determined from fixed reference points. Buoys should not be used to establish position. The present law does not make this distinction and buoys are misused. When a casualty occurs and a buoy is shown to have been off station, the Coast Guard can be held responsible for the casualty.

It is suggested that the first step in implementing this recommendation should be to survey vessel handling personnel to identify problem areas. It would then be desirable to study traffic patterns in some detail. This would involve gathering information on density and routing. The availability of such information varies with area. Simulation experiments could be designed to determine the optimal number and positions of aids. The experiment results should have the effect of minimizing disputes about modifications to the present system of aids (so should the early involvement of waterway users in identifying problem areas). Experimentation costs would have to be assessed but are anticipated to be reasonable in relation to the potential for cost savings over time as a result of improving efficiency of the aids system.

The Coast Guard would have primary responsibility for implementing this recommendation, both for initiating an assessment of specific needs and for introducing changes in the system of aids to navigation. Cooperation between the Coast Guard and the Corps of Engineers would be necessary for certain types of improvement such as the marking of bridge supports. It might also be necessary for railroads to cooperate for the marking of railroad bridges. Vessel handling personnel, contacted through their associations, unions, or companies would participate by identifying problem areas and possibly by agreeing to check for and report off-station buoys and otherwise defective aids.

Assessment of Expected Benefits. Discussion of benefit assessment is deferred until Recommendation 4 has been presented. The expected benefits are so similar that they may be considered together, at least at the level of detail that can be provided here, prior to identification of specific innovations.

4. For towboat navigation, there is a need for marking vertical bridge supports (piers) and dikes along the river.

Rationale. The marking of bridge supports was brought up in the discussion of aids to navigation. It is recommended explicitly and separately here because it is apparently very much wanted by river vessel personnel. In a previous ORI study of bridge collisions, towboat captains and pilots consistently stated the need for improved aids at the five, high-casualty bridges studied, and, in particular, called for retroreflective markings on bridge piers (Dayton, 1976). The operators themselves got together and marked the piers of one bridge with tape, which they report has held up satisfactorily for more than a year. The observations made on river towboats during the task analysis indicated that bridge supports are impossible to identify on radar since the return of the bridge itself masks the supports. Moreover, under certain atmospheric conditions (haze, smoke, drizzle, etc.), the bare concrete supports are difficult to see unaided during daylight operations and are poor reflectors of the towboat's searchlights at night, particularly, since aged concrete readily absorbs light. This problem was brought up repeatedly in conversations with towboat personnel throughout the trips. The towboat operators suggested the use of reflective tape (above the high water mark) and of radar transponders to assist them in identifying the location of bridge supports.

Another common complaint heard during the task analysis observation trips was about the difficulty of determining the position and extent of dikes (low piles of stone extending from the shore into the water) when they are partially or fully obscured because of seasonal variations in water level. It was suggested that dikes be indicated by fixed aids extending above the high water level and bearing standard navigational markings. The use of retroreflective tape for nighttime visibility was also suggested. Severe damage results when a towboat grounds on the huge stones that compose a dike, and that is a potential hazard for approximately one-third of the year. Moreover, if the water level is sufficiently above the dike and the current strong, the current may cause the barge train as well to be dragged over the dike. (The water does not typically rise high enough to allow a vessel to pass over a dike safely.)

One additional need related to dikes was voiced by towboat personnel—for better dissemination of information about the placement of new dikes. It appears that they often do not find out about new dikes until they encounter them or are warned by other operators on a run.

Marking bridges with retroreflective tape would clearly be a relatively simple and inexpensive innovation. Installation and maintenance of lights and radar transponders would be more time-consuming and costly, but would not appear to be prohibitively so. Care must be taken not to introduce too many transponders in one locale, as that might cause confusion.

Feasibility and Locus of Responsibility. Referring back to the preceding discussion of the system aids to navigation, it would seem efficient to make these bridges effective as aids to navigation and then eliminate some of the existing buoys. On certain segments of the river there are numerous bridges. Near New Orleans, for example, there is a bridge about every 10 miles.

The Coast Guard has responsibility for aids to navigation. However, the Corps of Engineers has responsibility for the construction of dikes and highway bridges. Cooperation between the two agencies is thus necessary. The aids to navigation should be taken care of in the construction of any new dikes and bridges. Some plan for modification of existing structures would have to be developed. As indicated in discussion of the preceding recommendation, the railroads would have to be involved in modifications to their bridges.

Assessment of Expected Benefits. For assessment of aid system modifications that may result from Recommendations 3 and 4, the following may be suggested at this time:

- Pretesting of proposed modifications by means of computer models would be appropriate where a problem clearly exists and there is significant uncertainty about the effects of possible solutions. It should be possible to establish a degree of confidence without resorting to real-time simulation. The costs and benefits of this kind of pretesting would have to be weighed.

- User opinion would seem to be the most suitable basis for post-implementation of the benefits of modifications. Implementation probably would be done incrementally with each increment followed by user assessment to take advantage of experience in implementation and avoid a burdensome effort. It would be desirable for users to evaluate the positioning and visibility of any new aid and to rate any change on a negative-to-positive scale in relation to previous conditions.

- For selected areas of high casualty incidence, it may be desirable to study pre- and post-implementation casualty data to determine whether innovations resulting from these recommendations may be associated with any changes in casualty patterns.

5. Indoctrination to the specific features, characteristics, and procedures of the vessel and its particular equipment should be given to all personnel.

This recommendation applies mostly to tankers and other deep draft cargo vessels because of the more frequent personnel changes. Towboat personnel work for particular companies and tend to be assigned to the same vessel for long periods.

Rationale. Indoctrination of new personnel is important given the fact that a ship's crew, with the usual exception of master, chief mate, and chief engineer, changes very frequently. Owners/operators do not hire personnel directly, but rather through the union halls, where personnel are assigned to openings on a first-come-first-picked basis. Also, it is not uncommon for seamen to leave the ship at the port of destination instead of making the return voyage, or even to leave at intermediate stops.

The FJA task statements stress the importance of two types of knowledge—functional (general) and specific. Functional knowledge can be attained in schools or courses, by working in the marine environment, and through other experience. Specific knowledge must be obtained by learning the details of a particular job in a particular work setting.

The observations and interviews conducted for the task analysis suggested that indoctrination practice varies greatly. It appears that, typically, little if any specific indoctrination is programmed.

With regard to a specific type of indoctrination need, Recommendation 1 dealt with the absence of standardization in basic vessel equipment design characteristics and configuration. It cannot be assumed that new personnel will be familiar with equipment they must use, let alone with the capabilities of equipment available to fulfill other functions which may be related to theirs. The personnel may never have worked with the equipment they encounter or they may have used it so long ago that they need to become familiar with it again.

A related point is that the life of training effects may be relatively short. Research on this possibility was beyond the scope of the task analysis. It was observed, however, that personnel who have recently renewed or upgraded their licenses seemed to make a more conscious effort to do tasks more formally (e.g., plot radar targets and CPA) than did others, who tended to substitute seaman's eye and estimation.

Again, we have no basis from the task analysis for stating that this is typical in the fleet, but it appears likely. The "fade-out effect" has received the attention of evaluators of educational and training activities outside the maritime field (Alter, 1963; Anastasi, 1958). The subject has been of particular concern in debates over federally-funded compensatory education for children (Campbell and Frey, 1970). One-shot training is not likely to have long term effects. Continuing infusions appear to be necessary, particularly when experience does not demand frequent, continuing application of training content.The upgrading and update training available in the maritime field satisfy some needs of this kind. Giving and receiving onboard indoctrination would complement what formal training programs can do to provide continuing training experience.

Feasibility and Locus of Responsibility. The recommendation for planned onboard indoctrination is believed to be quite simple and inexpensive to implement.

- Support of the concept by the upper managers of towboat companies. This support might be first demonstrated through an indoctrination policy statement, with continuing demonstration of interest (not just a pro forma written statement). Upper management should initiate whatever organizational effort might be needed (it should not be a great deal) to develop general guidelines for effective indoctrination approaches on their vessels and should facilitate the obtaining of back-up materials (such as sufficient equipment maintenance manuals; copies of standard operating procedures).
- Support of the concept by the masters, chief mates, and chief engineers, who are the most appropriate vessel personnel to oversee and perhaps conduct indoctrination.

Coordination with the union-sponsored training organizations might be desirable. The training organizations could possibly help with the development of approaches.

Shipbuilders and equipment vendors already supply technical materials on equipment design, operations, and maintenance. They might be enlisted to make such materials more usable by onboard personnel at various levels, if such a need should be identified.

This recommendation is meant to suggest a flexible, informal activity, but one that is planned and conducted systematically. The task statements

concerning indoctrination and personnel supervision offer guidelines for what might be done. (See Task Statements under Objectives V.A and V.B, Appendix F, pp. F-180 through F-186; also Task Statements under Objective III.A and III.B in Appendix G, pp. G-105 through G-111.)

The recommendation is seen as practical, simple, and clearly in the direction of promoting safe vessel operations. Thus, it could conceivably be accepted without rigid specification as a regulatory requirement. It might be necessary, however, for the Coast Guard to establish a formal mandate. Companies could attest to compliance. Periodic Coast Guard review of practices might be employed as a further check. However, it is believed that unless the practice of personnel indoctrination is done willingly because of belief in its merits, it is unlikely to be done effectively.

Assessment of Expected Benefits. The expected benefits of this recommendation include:

- Improved job knowledge and skills of vessel personnel
- Improved knowledge and awareness of crew members' capabilities, job demands and constraints on the part of supervisors
- Greater likelihood of safe vessel operations.

Similar to previous recommendations, the general assessment strategies that might be employed include

- Survey of personnel to obtain their assessment
- An assessment based on some form of measurement of personnel before and after implementation of the recommendation on a partial or full scale, and/or a measurement of personnel who did receive indoctrination vs a comparison group who did not.

It is believed that indoctrination or the lack thereof would be difficult to relate to casualty occurrence, particularly if implementation were voluntary and partial. If the personnel believe the activity has value, and/or if it can be shown that the activity enhances personnel knowledgeability, it would seem reasonable to accept the proposition that the activity increases the likelihood of safe vessel operations.

Recommendations Related to Data Synthesis Tasks

6. More effort should be made to have tanker and other cargo ship personnel remain with the same ship, the same route, and the same bridge crew.

Rationale. In the previous section of this report, reference was made to data synthesis tasks, represented in the task analysis by the "examine and

evaluate" tasks, in which the total data input (from the ship and environment) was analyzed to decide on the appropriate action to take. The data synthesis tasks are the crux of the decision-making process; it is in these tasks that judgment, intuition, and accumulated experience are marshalled to provide a solid basis for choosing the correct and most expeditious alternative. Familiarity and permanency with a particular vessel, route, and crew can add immeasureable information to the analysis process. If the person in charge clearly knows the capabilities of vessel and crew, he not only has more data to work with, but also can be more confident that the data are reliable. He then can place more confidence in his decision; he is more likely to feel that he can predict the outcome of his decision more accurately. Unfortunately, the variability of ship assignments is detrimental to the development of accumulated expertise based on familiarity with the work environment.

Support for more standardization of assignment (or at least a more permanent association between personnel and a specific company) comes from the Maritime Transportation Research Board study, The Seagoing Workforce (National Academy of Sciences, 1974). It suggests (p. 47) that seamen lack a sense of allegiance to a specific company, which "can instill a casual attitude toward the concept of a career in the merchant marine, and can limit or discourage the motivation to identify as a seaman and to remain a member of the seagoing workforce."

Automation, repetitive tasks, or lack of variation in assignment may cause boredom or low morale, which may lead to general job dissatisfaction and possibly to inattention and active forms of risk-taking behavior. However, the solution to such problems does not lie in assigning personnel haphazardly to a variety of vessels to spice up their experience. There is no single solution, but there are ways to improve negative conditions.

The Norwegians, for example, have tried to instill a sense of pride and responsibility in their personnel through decentralizing ship management, giving the crew control of day-to-day planning (National Academy of Sciences, 1974). This gives the crew members a feeling of involvement and control over the work place. The Norwegians have also applied the concept of job interchangeability (also called dual purpose or multipurpose crewing) to increase variety in the jobs of individual personnel. This is a procedure in which crew members have work roles in departments other than their own. It allows for greater flexibility in ship operations and more economic use of seamen. It also expands the individual's repertory of skills, which may give him more employment options. While interchangeability works particularly well for engine and deck personnel, possibly some variation of the program would be applicable to bridge personnel. The task analysis amply demonstrates the redundancy in their work.

Crew stabilization would make it easier to adjust the work organization to alleviate problem conditions such as fatigue and boredom. At the same time all personnel would have the opportunity to become thoroughly familiar with the work situation.

It has not been proven whether situation-specific experience is associated with maritime casualties. (Nor has a "causal" association been established between general maritime experience and casualty incidence, although there are experience requirements for licensing.) Age and exposure are two of numerous possible confounding variables. A fairly recent simulation experiment conducted at the Netherlands Ship Model Basin (NSMB) demonstrated the potential complexity of such analysis and also indicated that it is necessary to consider specific experience (Paymans, June 1976; Paymans and Witt, 1976). Pilots experienced on small tankers and newly-trained pilots without operating experience were asked to maneuver a supertanker through a difficult, curved channel into port. The experienced pilots did not do as well as the inexperienced pilots. The reason apparently was that the experienced personnel were used to handling much smaller ships, and were transferring that experience where it did not apply. The newly-licensed personnel did not have inappropriate expectations about ship response.

Commense sense suggests that familiarity with the work situation should promote more effective performance, other factors being equal. One of the few indepth accident analyses performed within one particular occupation (the roofing industry) which took into account accident rates of inexperienced vs experienced (apprenticeship vs journeymen) personnel showed that "the accident rate of apprentice roofers appears to be twice that of roofing journeymen" and that the findings "suggest a very strong accident avoidance learning curve during the first few months of work experience. In other words, inexperienced roofers incur an extremely high initial accident rate which drops rapidly during the first few weeks and months on the job." The study was performed for the National Institute for Occupational Health and Safety (Theodore Barry and Associates, June 1975, p. 5-1).

Of course, the roofing industry is very dissimilar to the merchant marine industry, and there are difficulties inherent in this type of research (as described above), but it does lend some support to the hypothesis that inexperience may be a factor in accident causation.

Feasibility and Locus of Responsibility. Implementation of this recommendation would require agreement from the maritime unions and the owners/operators. The Maritime Administration would be involved. It is expected that the Coast Guard would initiate an exchange between the parties, or open the exchange by interaction with MarAd, and would participate in some, if not all of the discussion. As the foregoing implies, implementation by consent of the parties is recommended.

It is noted that stabilization of crew assignments would require establishment of a rotation system, e.g., there might be two crews for each vessel, which alternate. Other considerations include possible effects on the distribution of maritime unemployment, and also personnel costs (although there should not be great changes from present costs on the whole).

The development of rotation systems would provide a good opportunity to assess the duration of tours of service. The current pattern is 6 months on, 6 months off. This pattern appears to be historically based. It should

be possible to arrange rotations that would enable ship personnel to have more normal private lives and family relationships. It also seems very likely that shorter rotation intervals would alleviate problems of boredom, fatigue, alienation and associated psychological manifestations. In addition, shorter breaks in service should help to minimize reductions in skill levels and blurring of knowledge that may occur when personnel are away from their jobs for long periods. For regular operations over particular routes, it would appear to be quite easy to establish regular suitable-duration rotations for alternate stable crews. The task analysis of course does not allow us to suggest an optimum duration and indeed there may be no single optimum because of situational and individual differences. Again, flexibility is strongly recommended. The people managing and performing the operations should have options to work out rotations meeting their needs, with the objective of improving the work situation, and the safety and cost effectiveness of operations. Union guidelines might well be established to assure that the interests of ship personnel are protected.

Assessment of Expected Benefits. The expected benefits of increasing the stability of crew makeup are similar to those outlined for the preceding Recommendation 5 to introduce systematic indoctrination of new personnel. In fact, to an extent, Recommendation 6 would substitute for Recommendation 5; reduction in personnel turnover would reduce needs for indoctrination/orientation.

The expected benefits of Recommendation 6 are:

- Improved job knowledge and skills of vessel personnel at all levels.

- Improved knowledge and awareness among crew members of each other's capabilities, job demands and constraints, and transient states that may affect task performance.

- Improved knowledge and awareness, on the part of supervisors, of crew members' capabilities, job demands and constraints, and transient states that may affect task performance.

- Potential for development of a psychologically more favorable work situation in which personnel at all levels may develop a greater sense of identity with each other and with the work; also, a situation in which it is easier to introduce innovations to increase the variety of the work and to afford ship personnel the opportunity for more normal personal lives.

- Improved likelihood of safe vessel operations.

It is believed that realization of these benefits can best be assessed by surveying personnel to determine their opinions about the change. It would also be possible to devise a measure of skill, knowledge and attitudinal parameters; the measure could be administered before and after implementation and to

comparison groups on ships where no change was introduced (assuming cooperation from owners/operators and the maritime unions).

Since implementation by consent is suggested, it might be more difficult to relate casualty occurrence to implementation of this recommendation. Casualty-based assessment is not ruled out, however, over the long term.

SUGGESTIONS FOR CASUALTY DATA COLLECTION

The ultimate measure of any action intended to improve the safety of merchant vessel operations is how it affects casualty incidence. Some of the difficulties of establishing that relationships have been alluded to in discussing assessment of expected benefits of the various recommendations made in this report. It was stated several times that in order to improve the prospects of casualty-based assessment, improvements in the data provided by casualty reports would be desirable.

As previously stated, revision of casualty report forms and guidelines for investigators should be based on a study of the present forms and guidelines as well as the findings from research projects that have employed the existing data. In general, more detailed information about the accident locale and environment, the vessel characteristics, historical information on the vessel's runs, and data on the pilot's/master's activities/duties/work history preceding the accident could provide data to develop accident-pattern hypotheses and to more clearly define safety issues. Some of the particular data elements that appear to be needed include:

- <u>for tankers/freighters</u>

  a. Was vessel outbound or inbound?

  b. Did master/mate on watch have in-port duties prior to departure or did he have other non-watchstanding duties (such as tank cleaning) prior to inbound transit?

  c. If pilot was onboard, how many trips did he make in the last 24-48 hours? What was the length of time per trip?

  d. Was the mate on watch familiar with the accident locale?

  e. If pilot was onboard, had he handled this vessel before? If so, with what frequency?

  f. How long has master/mate been onboard—total? Since last vacation? Was he regular or relief?

  g. What collision avoidance system was onboard? Was it in operation?

  h. What were the water conditions?

• <u>for towboats</u>—

a. How many loads were attached?

b. How long had pilot been onboard—totally? This particular sailing cycle?

c. Was the towboat-barge array sailing upriver or downriver (if applicable)?

d. What was towboat draft and draft of deepest drawing barge?

e. What were the water conditions?

f. What was the overall displacement of towboat-barge array?

SUMMARY COMMENT ON THE RECOMMENDATIONS

It has been stated that the primary intent of this task analysis was to lay out the task demands on bridge personnel in relation to actual operating conditions. It is believed that the task data suggest a number of present requirements and conditions to which additional research should be directed. The analysis pointed up the cerebral nature of the work of the person in charge of vessel control, the requirement for sustained alertness under often lulling conditions, and dependency on equipment and information sources that do not appear to measure up to what today's system design and hardware development capabilities would appear to make possible. The decision-making processes and improved means of supporting those processes (through organizational change and equipment development, for example) are considered important areas for future research.

For the short run, there appear to be a number of less than optimal conditions of merchant marine operations that could be corrected with fairly modest effort. A need for elementary standardization has been identified, which includes establishment of basic performance standards for vessel control equipment and improved means of assuring that personnel have adequate knowledge of the specific conditions under which they work. The latter might be accomplished by planned onboard indoctrination and/or a move toward reduction in crew turnover. It also appears that improvements could be made in the system of aids to navigation, to provide more help to vessel personnel and to make system maintenance less burdensome to the Coast Guard.

The action recommendations made in this report are put forth as desirable objectives toward which the maritime community should begin to move. The cooperation of all segments would be required; none of the recommendations can be accomplished by the Coast Guard alone. We believe this is appropriate, in fact essential, since the purpose is to improve the safety of a large and complex system and the results will depend on the efforts of many members at all levels. Given leadership (seen as the Coast Guard's contribution, at least initially), cooperation, and follow-up, it should be possible to accomplish all of these objectives reasonably soon.

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Fine, S.A. and W.W. Wiley, An Introduction to Functional Job Analysis: A Scaling of Selected Tasks from the Social Welfare Field, Methods for Manpower Analysis No. 4. Washington, D.C.: The W.E. Upjohn Institute for Employment Research, September 1971.

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Hill, J.H., J.F. Utegaard, and G. Riordan, Dutton's Navigation and Piloting. Annapolis, Maryland: U.S. Naval Institute, 1959.

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National Academy of Sciences, The Seagoing Work Force: Implications for Technological Change. Washington, D.C.: NAS/NTRB Panel on Human Resources in U.S. Maritime Industry, September 1974.

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Operations Research, Inc., Spill Risk Analysis Program: Methodology Development and Demonstration, Volume I (review draft). Silver Spring, Maryland: Operations Research, Inc. Technical Report 964, October 1975.

Paymans, P., "Human Factors in Ship Handling" (in-house paper). Netherlands Ship Model Basin, Wageningen, The Netherlands, June 1976.

Paymans, P. and F. G. W. Witt, "Some Aspects of the Acquisition of Skill in Controlling Ships." Paper presented at the Symposium on Marine Transportation Systems, The Hague, 1976.

Porricelli, J., V. Keith, and B. Paramore, Recommendations for Qualifications of Liquefied Natural Gas Cargo Personnel. Washington, D.C.: U.S. Coast Guard, Office of Research and Development Report No. CG-D-53-76. (NITS Accession No. AD-A026108, April 1976.)

Stoehr, L. and B. Paramore, Handbook for the Development of Qualifications for Personnel in New Technology Systems. Washington, D.C.: U.S. Coast Guard, Office of Research and Development Report No. CG-D-75-76. (NTIS Accession No. AD-A027526, February 1976.)

Theodore Barry and Associates, Behavioral Analysis of Worker and Job Hazards in the Roofing Industry. Prepared for the National Institute for Safety and Health, Cincinnati, Ohio, June 1975.

Turpin, E.A. and W.A. MacEwen, Merchant Marine Officers' Handbook. Cambridge, Maryland: Cornell Maritime Press, 1975.

Wentworth, R.S., J.V. Noel and F.L. Caudle, Knight's Modern Seamanship (revised). Princeton, New Jersey: D. Van Nostrand Company, Inc., 1957.

APPENDIX A

BACKGROUND OF LITERATURE REVIEW, ANNOTATED BIBLIOGRAPHY, AND LIST OF ORGANIZATIONS CONTACTED

The information gathering involved literature search and contacts with union training organizations and operating companies.

LITERATURE SEARCH

The literature search focused on five basic areas:

1. General background information, including review of licensing, qualifications, and other pertinent maritime/shipping rules and regulations.

2. Review of marine accident information and accident analyses that have been performed.

3. Investigation of psychological factors and attitudes apparently associated with accident occurrence, including the latest evaluations of the "accident proneness" hypothesis.

4. Information on existing safety analysis methods that could be of value during or following a task analysis.

5. Previous job or task analyses or other kinds of information about the work of vessel control.

The background material reviewed consisted of U.S. Coast Guard qualifications and licensing procedures and national and international quidelines, rules and regulations governing marine transportation, navigation, communications, and vessel manning requirements.

A review of marine accident data has been carried out by ORI as a part of the Spill Risk Analysis Program. Therefore, various analyses of the factors involved in collisions were immediately available to the study team. Data on bridge rammings in river navigation is also available from another ORI study for the Coast Guard. A search of the literature was made for other studies providing first-hand information about maritime collisions, groundings or rammings.

A review of the psychological literature on characteristics of personality and performance thought to be related to accident causation began with the concept of "accident proneness." The concept of accident proneness as a stable and permanent personality characteristic was proposed by Greenwood and Woods in 1919 on the basis of analysis of the distribution of accidents among workers in British munitions factories (Greenwood and Woods, 1919). This concept was the subject of numerous investigations over the following years and continued to be widely accepted by behavioral scientists as late as the 1950s.[1] Today it is most commonly believed that accidents are largely situationally determined by an interaction of the person and his environment. Various new terms have been proposed to describe persons who have more than their share of accidents—temporary accident proneness, variable accident tendency, accident repeater. Viewed in this way, it is conceivable that any worker could be considered accident prone at some point in his life. The temporary nature of psychological stresses which might bring about accidents has been a major problem for researchers trying to isolate and measure personality characteristics associated with accident causation. Often, trait measurements are made months or years after the occurrence of accidents, so concrete evidence is hard to find in support of even a "temporary" accident-proneness theory.

In general, research on personality variables that may relate to accident occurrence suffers from a number of technical difficulties:

- The difficulty of obtaining reliable and valid measures of personality variables
- The difficulty of determining what is cause and what is effect

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[1] See, for example, F. Dunbar, Psychosomatic Diagnosis. New York: Harper & Bros., Medical Book Department, 1943. K.A. Menninger, "Purposive Accident as an Expression of Self-Destructive Tendencies," International Journal of Psychoanalysis, 17:6-16, January 1936, also Man Against Himself. New York: Harcourt, Brace & Co., 1938. A.J. Rawson, "Accident Proneness," Psychosomatic Medicine, 6:88-94, January 1944; "Accident Prone Personality: A Preliminary Study," Personnel, 33:29-32, 1965; A. Davids and J.T. Mahoney, "Personality Dynamics and Accident Proneness in an Industrial Setting," Journal of Applied Psychology, 41:303-306, 1957; R. de Reamer, "Accident Proneness: Fact or Fiction," Supervisory Management, 3:12-14, 1958.

- The question as to whether the personality characteristic under consideration is a stable trait or a temporary one that may even be situationally determined.

Efforts have been made to relate attitude toward risk with accident occurrence. However, the nature of the relationship is still unclear. Research also has focused on the relationship between attitudes about work and work-related accidents. One recent study found a difference in attitude about the pace of work between workers who had a high accident record versus those who had a low record (Theodore Barry and Associates, 1975). The high accident workers felt more pressure to work faster throughout the day. However, this study was done in a high-risk industry (roofing), and the results may not be able to be replicated for other less dangerous professions.

A number of publications were investigated to obtain information on safety analysis procedures that could be used during or after the performance of a task analysis to point out safety hazards associated with particular tasks or job flows. Two particularly helpful publications were obtained. One of them, Handbook of System and Product Safety by Willie Hammer, gives an overview of all major safety (hazard) analysis techniques. The other, Psychological Behavioral Strategies for Accident Control, A System for Diagnosis and Intervention, produced by the Westinghouse Electric Corporation Behavioral Safety Center for the National Institute for Occupational Safety and Health, also reviews standard safety analyses techniques. However, it combines these standard approaches with organizational diagnostic procedures such as job attitude measures, job analysis procedures, and organizational structure to produce a safety analysis and intervention system for use by companies in accident prevention programs. The approach includes diagnostic safety forms to pinpoint hazardous conditions which might exist and then suggests actions to be taken depending on the outcome of the diagnostic review. While this group has developed an innovative approach to safety analysis, it would be difficult to use this system in the marine environment since it requires the completion of extensive questionnaires by a number of people (foreman, worker, training, direction, etc.) who work within a formalized industrial environment which already has a sophisticated safety and training program and in which workers who are familiar with the environment can spend the time completing forms necessary for the analysis.

A review of previous job analyses in the marine environment pointed to the work of Thomas Mara as the most useful source of task information for tankers and cargo vessels. Volumes I through III (1968) of his series proved particularly helpful. The tasks are designated but not described in detail, and they follow the traditional allocation of duties in a time sequence rather than proceeding deductively from overall system-oriented objectives. Thus the Mara report was most useful in this study for designating tasks for further analysis and for preparing the prliminary flows of tasks prior to shipboard observation.

The remainder of Appendix A lists the specific books, articles, reports and studies reviewed and the organizations, agencies and libraries contacted during the course of the literature review to obtain these materials

or other pertinent information. (Some organizations had no information to give and some gave only verbal information which, in certain cases, was given in confidentiality.)

BIBLIOGRAPHY OF WORKS REVIEWED FOR TASK II

Alexandrov, M., "Probabilistic Approach to the Effectiveness of Ship Lifesaving Systems," Leningrad Shipbuilding Institute, Society for Naval Architecture and Marine Engineering, New York, New York, 1970.

Abstract: Statistical analyses of ship losses and comparison of ship distress time and lifesaving operation time factors. Main criterion is probability of favorably accomplishing the lifesaving operation.

American Institute for Research, AIR Research Notes, Nos. 4, 6, 9, 13, Palo Alto, California, 1951, 1953, 1957.

Abstract: Short articles on job analysis procedures, human factors in accidents (accident proneness, temporary conditions, age and experience, equipment, and specific factors), research on linear accidents (collection by "at source" vs "group" method).

Department of the Army, Office of the Chief of Engineers, "Waterborne Commerce Statistics," Washington, D.C., October 1970.

Abstract: Information on data collection procedures and coding used by Corps of Engineers. Description of forms used, how tabulations are done, types of data collected, extent of program, types of output.

Barrett, G.V., *et al*., "Analyses of Performance Measurement and Training Requirements for Driving Decision-Making in Engineering Situations," University of Rochester, Rochester, New York, June 1973.

Abstract: Determination of feasibility of developing procedures to measure driver decision-making performance, and feasibility of improving decision-making through training. Critical kinds of situations or emergencies identified, and boundaries of decision-making process clarified. Risk taking hypotheses were researched and de-emphasized.

Bates, C.C. and P. Yost, "Where Trends the Flow of Merchant Ships?," for inclusion in Proceedings of 8th Annual Conference, Law of the Sea Institute, University of Rhode Island, June 1973.

Abstract: Figures on the number of ships, types of ships, tonnage worldwide, routes and ports preferred, world port tonnage. Brief data on frequency and nature of casualties in the world merchant fleet and measures being taken to ameliorate marine pollution.

Behavioral Safety Center at Westinghouse Electric Corporation, Psychological Behavioral Strategies for Accident Control, A System for Diagnostic Intervention, Technical Report BSC-3, prepared for the National Institute for Occupational Safety and Health, December 1974.

Abstract: This publication outlines a procedure for diagnosing existing conditions in a particular job which contribute to low levels of safety performance and then choosing among a set of intervention strategies which would alter the job requirements or redesign the work situation in such a way that accidents and illnesses would be reduced in specific job settings.

Bovet, D.M., "Preliminary Analysis of Tanker Collisions and Groundings," U.S. Coast Guard Applied Technology Division, Washington, D.C., January 1973.

Abstract: Collisions analysed in terms of vessel size, speed at time of occurrence, angle of collision, depth of penetration, geographic location. Correlations of penetration depth with striking ship speed, momentum, and energy are attempted.

Brobst, W.A., "Transportation Accidents: How Probable?," Nuclear News, May 1973.

Abstract: Covers package design parameters, accident statistics for truck, rail, barge, accident severity and damage, estimates of package damage.

Buchaca, N.J., et al., "Human Factors Problems in the Design and Application of Miniaturized Controls and Displays," Naval Electronics Laboratory Center, San Diego, California, June 1966.

Abstract: Survey of commercially available miniaturized controls and displays to determine the degree to which deleterious effects are recognized. Dangers of miniaturization and alternative approaches discussed.

Caplan, R.D., "Job Demands and Workers' Health," Institute for Social Research, University of Michigan, April 1975.

Abstract: Examination of psychological stresses in the job environment and the impact of stress on affective and psychological strains, and on illness reported by the worker.

Carpenter, M. and W. Waldo, "Automated Collision Avoidance: A New Look at an Old Problem," Maritime Institute of Technology and Graduate Studies, Linthicum Heights, Maryland, 1974.

Abstract: Options when risk of collision is imminent, economics of collision avoidance systems. Emphasizes systematic observation, relative motion when using radar. Shows stabilized and unstabilized radar displays when dependent and independent relative motion is present.

Carpenter, M. and W. Waldo, "Electronic Navigation Requirements of the Merchant Marine Deck Officer," Journal of the Institute of Navigation, Volume 21, No. 2, Summer 1974.

Abstract: Results of questionnaire prepared by Institute and given to 120 advanced grade deck officer students. Questionnaire covered kinds of equipment used, choice of equipment, minimum accuracy desired, etc.

Chaudhari, D.R., "Analyses of the Coastal Tank Vessel and Barge Traffic (Design and Development of System Alternatives to Identify and Locate in Ballast Tank Vessels and Barges), Optimum Computer Systems, Washington, D.C., April 1973.

Abstract: Analysis of coastal tank vessel and barge traffic in in terms of petroleum traffic tonnage, tank vessel trips, major shipping and receiving areas, and identification of high density traffic areas. Objective is to design system alternatives for identifying and locating tankers and barges to be diverted to scene of a stricken vessel.

U.S. Coast Guard, Proceedings of Marine Safety Council, Department of Transportation, Washington, D.C., September 1974.

Abstract: Topics include watch arrangements, fitness for duty, navigation, lookout, navigation with pilot embarked, and protection of marine environment. Includes article "Basic Principles and Operational Guidance for Navigational Watchkeeping," from Intergovernmental Maritime Consultative Organization (IMCO) November 1973 resolution.

U.S. Coast Guard, "An Analysis of Oil Outflows Due to Tanker Accidents, 1971-1972," Washington, D.C., November 1973.

Abstract: Analysis of groundings, collisions, structural failures, explosions. Presents impact of total losses and analyses by deadweight, structural failures by vessel age, geographic location, area, and registry.

U.S. Coast Guard, "Licensing - A Program for the Seventies," Washington, D.C., May 1969.

Abstract: General recommendations from the Shimberg Study of 1968. Presents picture of what improvements should be instituted, and those improvements which have already been implemented.

U.S. Coast Guard, "Bridge-to-Bridge Radiotelephone Communications Requirements," in Proceedings of the Marine Safety Council, Washington, D.C., September 1972.

Abstract: Vessel Bridge-to-Bridge Radiotelephone Act and Coast Guard and Federal Communications Commission regulations.

U.S. Coast Guard, "Comparative Study of Selected Marine Collisions Occurring During Six Fiscal Years of 1957, 1958, 1959, 1967, 1968, 1969, Washington, D.C., April 1971.

Abstract: Covers collisions under Coast Guard jurisdiction, but excluded those on western rivers and ships under 500 gross tons. Gives information as function of tonnage, rules of road violated, passing signals, visibility, radar and radiotelephone involvement, results of collision, etc.

U.S. Coast Guard, "Chemical Data Guide for Bulk Shipment by Water," Washington, D.C., 1973.

Abstract: Charts on fire and explosive hazard data, health hazard data, reactivity data, and spill or leak procedure information for approximately 200 chemicals.

U.S. Coast Guard, "Oil Pollution Control for Tankermen," Washington, D.C., February 1973.

Abstract: Information on certification test for tankermen. General information on discharge containment and cleanup, disposal of sludge and waste, sample examination questions and answers.

Department of Commerce, "Waterborne Exports and General Imports, Calendar Year 1970," Washington, D.C., August 1971.

Abstract: Trade areas, district, ports, type of service, and U.S. flag information given in chart form on segment of U.S. foreign trade exported or imported by vessel.

Crane, L., "Maneuvering Safety of Large Tankers: Stopping, Turning and Speed Selection," Society of Naval Architects and Marine Engineers, November 1973.

Abstract: Devices and procedures for improving stopping of tankers examined. Parameters such as size, speed, loading condition, etc., included. Results indicate importance of approach speed to the decision to crash astern or to turn.

Ferrell, H., T. Noble, and W. Carsen, "Final Research Report of Ship's Bridge Control Console: Operational Evaluation of Benefits, Limitations, Recommendations," Sperry Piedmont Corp., Charlottesville, Virginia, October 1966.

Abstract: Summary of efforts to develop an integrated bridge console for the Maritime Administration. Describes installation and field evaluation of console. Makes recommendations in areas of bridge design, maneuvering, motion control possibilities, surveillance, navigation, communication, centralization.

Fischkoff, B., "Hindsight: Thinking Backward," Oregon Research Institute, Eugene, Oregon, 1975.

Abstract: Knowledge of the outcome of an event is found to increase the perceived inevitability of the outcome reported. Failure to appreciate the effects of outcome knowledge can seriously prejudice the evaluation of decisions made in the past, and limit what is learned from experience.

Flanagan, J.C., "The Critical Incident Technique," Psyc. Bulletin, 51(4), July 1954.

Abstract: Basic discussion of critical incidence procedure. Major steps include determination of general aim of activity, development of plans and specifications for collecting factual incidents, collection of data, analysis of data, interpretation and reporting of statement of requirements of activity.

Ford, A., "Foundations of Bioelectronics for Human Engineering," Naval Electronics Laboratory Center, San Diego, California, April 1957.

Abstract: Description of equipment to measure physical responses and indication of measurements to be taken to monitor presence of various states (fatigue, manual and physical work, emotional stress, drugs, unfavorable environment, etc.).

French, D. and H.A. Richards, "Hazardous Materials Flow in Intercoastal Waterways - A Case Study of Risk-Exposure Factors for the Future of a Specific Area," Texas A&M University, for National Academy of Sciences Committee on Hazardous Materials, Washington, D.C., July 1973.

Abstract: Presents a method of quantifying, projecting and reducing the risk level for hazardous material barge movements. Methodology is developed showing how risk levels can be projected from past experience and that such levels are most dependent upon waterway features and human errors.

Gardenier, J.S., "Concepts for Analyses of Massive Spill Accident Risk In Maritime Bulk Liquid Transport," U.S. Coast Guard, Washington, D.C., June 1972.

Abstract: Definition of types of accidents, categories of risk factors, theoretical spills and their prevention, determination of both normal operations and range of anomalies, applicability of concepts to real world environment.

Gardenier, J.S., "Simulation and the Marine Safety Problem: Making the Application Drive the Design," U.S. Coast Guard, Washington, D.C., July 1973.

Abstract: Problems of quantifying costs and benefits of regulatory public safety programs in general, and relative to the risks

of transporting hazardous chemicals is described. Potential applications of computer simulation to spill risk management, along with limitations of simulations to marine safety is included.

Greene, K. and J. Cunningham, "Failure Mode Effects and Criticality Analyses," RCA, Princeton, New Jersey, 1968.

Abstract: Method for exposing failure modes and classifying and quantifying possible cause and associated probability of occurrence. Description of methodology and illustrative examples.

Griesenger, D.W., "Modeling Human Behavior Quantum Mechanically," Union College, Schenectady, New York.

Abstract: Two possible analogies with physics are proposed for definition of force for use in the behavioral sciences. Energy state in quantum mechanics is linked to emotional arousal.

Hammer, W., Handbook of System and Product Safety, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1972.

Abstract: This book presents a comprehensive description of various kinds of safety analyses in addition to information on components of a safety program, fundamental legal principles and liability issues regarding on-the-job accidents, basic concepts of hazards (determining existence of hazards, categories of hazards, etc.), and factors aiding the elimination of accidents.

Hansen, J.C., "Upgraded Third Generation Information Flow Requirements Analysis," Volume 2, Computer Sciences Corp., Falls Church, Virginia. September 1973.

Abstract: Report represents an initial effort to define requirements for communications in support of air traffic control operations for the period 1975-1985. The rationale, definitions and analyses leading to a formulation of communications requirements are presented. The basic methodology includes classification of information in terms of time-ordered relationships associated with communications in the past, present and future.

Hill, J., "The Seafaring Career," Tavistock Institute of Human Relations, Tavistock Centre, London NW3, England, January 1972.

Abstract: The loss of experienced men from the sea-going industry is looked at in terms of the total relationship between the employee and employer. Findings about the objective features of seafaring careers are examined statistically and from interviews in which the psychological, social and economic factors governing going to, remaining at, and leaving the sea are explored.

Hooft, J., V. Keith and J. Porricelli, "The Influence of Human Behavior on the Controllability of Ships," presented at the National Research Council Symposium on Hazardous Materials, New Orleans, Louisiana, April 1975.

Abstract: Consideration of complex interactive elements which are contributory factors to occurrence and activation hazards: ship's hydrodynamic characteristics, personnel skill levels, peripheral aids, effect of environment.

Indik, B.P. and I. Wolock, "Recent Findings Showing the Impact of the Organization on Individuals and its Relevance to the U.S. Merchant Marine," U.S. Seamen and the Seafaring Environment, Symposium Report, National Maritime Research Center, Kings Point, New York, September 1971.

Abstract: Summarizes studies providing insight into the psychological and sociological ramifications of being a seaman. It suggests that the declining industry and automation may reduce income and job satisfaction. Recommends that research should investigate the relationship between licensed and unlicensed seamen, the opportunities for leisure and recreation, the importance of physical accommodations and the impact of the seafaring occupation on the family.

Institute for Social Research, "Navy Manpower - Values, Practices, and Human Resources Requirement," Center for Research on the Utilization of Scientific Knowledge, University of Michigan, June 1973.

Abstract: Surveys of representative national civilian population, sample of Navymen stratified to be representative of ship and shore stations. Data concerns values, perceptions, and preferences in national and personal work settings. Includes preferences by age, education, region, sex, and race.

International Labor Organization, "Technological Change and the Merchant Seaman," Volume 92H4, Geneva, Switzerland, October 1965.

Abstract: General information and summaries of technical changes in various countries affecting merchant seamen. General recommendations on how to deal with such changes.

International Labor Organization, "Vocational Training of Seafarers," Geneva, Switzerland, September 1969.

Abstract: Brief description of various international conventions dealing with vocational training. Achievements of ILO member countries in respect to maritime training.

International Labor Organization, "Winds of Change," Geneva, Switzerland, 1970.

Abstract: Problems of seafarers, fisherman, dock workers, boatmen on inland waterways.

A.T. Kearney, Inc., "Domestic Waterborne Shipping Market Analyses," Executive Summary, Chicago, Illinois, February 1974.

Abstract: Profile of inland waterways, domestic ocean and Great Lakes trade volumes. Market trends are reviewed and suggestions for further growth are given.

Krumm, R., P. Schwartz and R. Fitzpatrick, "Principles and Procedures for Using Pilot Opinion Data," American Institute for Research, Pittsburgh, Pennsylvania, March 1960.

Abstract: Clarification of general area of utilization of pilots' opinions in evaluations of aircraft and aircraft components. Pilot variables such as experience and attitude factors are mentioned. Critical incident technique is described with details as to information content desired, format of questions, data collection procedure, etc.

Lazet, A., "Human Factors in Bridge Design for a Pilot Vessel," Ministry of Defense (Marine), The Hague, Netherlands, April 1969.

Abstract: Consideration of human engineering requirements while designing a bridge for pilot vessel.

Leeper, J.H., "Human Error in a Super System," presented at The 10 Million Ton Carrier Super Ocean Carrier Conference, San Pedro, California.

Abstract: Human error is defined and statements about the causes of errors are hypothesized including elements of panic, sickness, drunkeness, confusion, inattention, imcompetence, calculated risk and fear. Programs for reducing human error briefly discussed, and recommendations for future are made.

Leeper, J., "Human Error in Merchant Marine Safety," National Academy of Sciences, Washington, D.C., June 1973.

Abstract: Modified fault tree technique was used to analyze causes of marine casualties. Factors contributing to human error include panic, sickness, drunkeness, confusion, inattention, incompetence, calculated risk and fear.

Lichtenstein, M., "Studies in Human Control Dynamics," Naval Electronics Laboratory Center, San Diego, California, October 1957.

Abstract: Investigation of perceptual-motor capacities of people in persuant tracking and compensatory tracking tasks.

Madison, R.L., "Human Factors in Destroyer Operations," U.S. Naval Postgraduate School, Monterey, California, March 1974.

Abstract: Shipboard duties are considered in terms of related laboratory experiments and recommendations are made as to how equipment or environment can be changed to enhance performance.

Mara, T., et al., Human Factors in Ship Control, General Dynamics Corp., Volumes I-III, Groton, Connecticut, January 1968.

Abstract: Analysis of merchant vessel operations directed to development of human factor guidelines for bridge design, with recommendations for design change. Designation of tasks of all bridge personnel with associated information requirements. Frequency, duration, criticality and percent of total workload of tasks performed by deck watch officers are detailed.

Mara, T. and R. O'Hogan, "An Automated Collision Avoidance System for Ship Control Systems and Harbor Advisory Service," Radio Technical Commission for Marine Services, FCC, Washington, D.C., 1970.

Abstract: Describes marine digital systems and anti-collision system consisting of general purpose computer and peripherals, any commercially-available marine radar, radar interface, operator control, CRT display and optional automatic target processing unit.

Massachusetts Institute of Technology, Work in America, MIT Press, Cambridge, Massachusetts, 1973.

Abstract: Appendix contains 34 experiments attempting to humanize work and decrease stress such as boredom, simple tasks, repetitive tasks.

Moreby, D.H., "Toward a Sound Policy for Seafarers," Shipbuilding and Shipping Record, Transport and Technical Publications Limited, London, England, June 1970.

Abstract: Reasons for reduction in job satisfaction of ship's masters and senior officers. Recommended solution is the creation of a matrix-type officer structure in which each officer would be a specialist in one field and assistant in another. Importance of training stressed.

National Academy of Sciences, "A Study of U.S. Merchant Marine Safety Regulatory System," December 1970.

Abstract: Highlights regulatory redundancy in the construction and operation of merchant ships. Gives comparison of international regulations.

National Academy of Sciences, "Shipboard Manpower 1965: A Statistical Study of Men in the Privately Operated U.S. Flag Merchant Marine," Washington, D.C., 1965.

Abstract: Summary of characteristics (as of 1965) of work force manning privately operated U.S. Flag merchant marine: size, man-days worked, positions held, highest licence held or rating worked, union and union-management affiliation, age, length of service.

National Academy of Science, "The Seagoing Work Force: Implications for Technological Change," NAS/NTRB Panel on Human Resources in U.S. Maritime Industry, Washington, D.C., September 1974.

Abstract: Report on effects of technological development and of current wide-spread attitudinal changes toward work and authority in shipboard organizational effectiveness.

National Safety Council, "1972 National Safety Congress Transactions, Marine Safety," Chicago, Illinois, 1972.

Abstract: Two articles covering shipboard radar plotting and its safety and safety problems among longshoremen. Recommendations to enhance safety aspects of both topics presented.

National Safety Council, "1973 National Safety Congress Transactions, Marine Safety, "Chicago, Illinois, 1973.

Abstract: Topics include increased safety through VTS systems, marine casualty reporting review, developments in operational safety, new approaches to tanker safety.

National Safety Council, "1974 National Safety Congress Transactions, Marine Safety," Chicago, Illinois, 1974.

Abstract: Topics include design, construction, and operational safety of surface effect ships, Exxon casualty administrative program, improving tanker safety through casualty review, and maritime safety training at the Maritime Institute of Technology.

National Transportation Safety Board, "Study of Towing Vessel Safety and Accident Preventive Recommendations," Washington, D.C., August 1969.

Abstract: Compares accident data between inspected and uninspected towing vessels. Recommends upgrading Coast Guard compilation of casualty statistics involving uninspected vessels, requirement to license certain towboat operators, and study means of reducing fatalities.

National Transportation Safety Board, "Risk Concepts in Dangerous Goods Transportation Regulations," Washington, D.C., January 1971.

Abstract: Risk identification model is outlined. Phase I includes system identification; phase II involves risk evaluation procedure; phase III is development of actions required to reduce risk level.

National Transportation Safety Board, "Collisions Within the Navigable Waters of the U.S.: Consideration of Alternative Preventive Measures," Washington, D.C., 1972.

Abstract: Evaluates causes and potential results of collisions in navigable waters of U.S. Methods of preventing collisions and minimizing the potential losses resulting from collisions are considered.

Nealey, S.M., "Importance of Job Factors to Navy Personnel," Department of Psychology, Colorado State University, Fort Collins, Colorado, May 1972.

Abstract: Several hypotheses are presented concerning the concept of importance of job factors. Development of indirect 2-stage method for measuring importance is described. Respondents to tests were grouped by means of cluster analyses into homogeneous clusters with common patterns of job factor importance.

Netherlands Ship Model Basin, "International Jubilee Meeting on the Occasion of the 40th Anniversary of the Netherlands Ship Model Basin, August 30-September 1, 1972," Wageninger, The Netherlands, 1973.

Abstract: Articles geared toward engineering information; problems of ship resistence, wind resistence, developments in marine propeller hydrodynamics, cavitation, applied mathematics in ship hydrodynamics, maneuverability, ocean technology, etc.

Oceanographic Institute of Washington, "Study of Human Performance Related to Bridge Personnel on Maritime Vessels," Seattle, Washington, June 1975.

Abstract: Research study focusing on the collection and analysis of operational field data obtained by observing the activities of key bridge personnel (masters, mates, pilots) while operating commercial passenger vessels (ferries) and merchant vessels on the waters of Puget Sound, Washington.

Office of Technology Assessment, Congress of the United States, "Oil Transportation by Tankers: An Analysis of Marine Pollution and Safety Measures," Washington, D.C., July 1975.

Abstract: Covers approaches for reducing pollution and improving safety, including ship improvements, maintenance, personnel training and licensing information control systems, local port conditions, oil spill cleanup approaches. History of tanker growth, status and trends.

Operations Research, Inc., "Spill Risk Analysis Program: Human Factors Questionnaire," Silver Spring, Maryland, April 1973.

Abstract: Questionnaire covers topic areas of initial location across channels, communications, detection, decision-making, and maneuver execution.

Operations Research, Inc., Spill Risk Analysis Program, Interim Report No. 1, Accident Analysis, Silver Spring, Maryland, April 1973.

Abstract: Covers the collision process, collision types, time factor involved in meetings, method for analyzing casualty reports, development of logical structure for ship collisions, terminology in logic tree.

Operations Research, Inc., "A Discussion of Tasking of Shipboard Bridge Personnel, and Education and Training Related to Those Tasks," Silver Spring, Maryland, July 1973.

Abstract: Three categories of tasks developed: piloting, handling, and communications. Secondary and tertiary breakdown of these task areas, along with an outline of general categories of skills needed.

Operations Research, Inc., Spill Risk Analysis Program, Interim Report No. 5, Exploratory Analysis of Rammings and Groundings, Silver Spring, Maryland, January 1974.

Abstract: Rammings cover floating or submerged objects, fixed objects, ice, aids to navigation. Findings include discussion of casualty classes, data base for grounding analysis, means of preventing rammings and groundings.

Operations Research, Inc., "Collisions, Groundings and Rammings by Accident Location," Silver Spring, Maryland, February 1974.

Abstract: List of accident location of tanker or cargo vessels by casualty file location code.

Platt, E.H.W., "Operation, Maintenance and Manning Problems in Large Tankers," Fire Engineering, New York, New York, March 1971.

Abstract: Refers to tankers for carriage of crude oil with a deadweight tonnage of or greater than 2000,000 T. Problems created by size, including operational planning, ship operation, safety problems in ports, and work requirements for repair and maintenance crews.

Plummer, C.J., Ship Handling in Narrow Channels, Cornell Maritime Press, Inc., Cambridge, Maryland, 1966.

Abstract: Contains chapters on making suction an asset, anchoring, mooring, trimming, using tugboats advantageously, and using anchors to maneuver.

Poricelli, J., V. Keith and R. Storch, "Tankers and the Ecology," presented at the Annual Meeting of the Society of Naval Architects and Marine Engineers, New York, New York, November 1971.

Abstract: Sources, magnitudes, and ecological effects of oil pollution are presented. Includes worldwide tanker casualty analysis of incidents occurring during 1969 and 1970. Tanker design proposals described and analyzed in terms of need, effectiveness and practicality.

Prunkl, P.R. and R.B. Wiley, "Preliminary Application of the Critical Incident Technique to Combat Performance of Army Aviators," Alabama Psychological Association, May 1968.

Abstract: Description of ways in which ineffective aviators cope with stress. A modification of Flanagan's Critical Incident Technique was used in the recording of incidents characterizing effective or ineffective performance, and observations were categorized according to a behavior model.

Radio Technical Commission for Marine Services, RTCM Assembly Meeting, "Symposium Papers, Safe Ship Operations," Volume 2, New Orleans, Louisiana, April 1972.

Abstract: Articles on components of practical collision-free system, trends in instrumentation for navigation, integrated shipboard communication systems, operational specifications for marine CAS, advanced CAS, and accuracy limitations of radar with respect to ship.

Rochester Institute of Technology, "Risk-Taking in Skilled Task Performance," Rochester, New York, October 1974.

Abstract: Predicted relative accident rates vs function of a two-factor risk-taking model (need for achievement and locus of control). General and situation-specific tests were used.

Rook, L.W., "Reduction of Human Error in Industrial Production," Sandia Laboratories, Alburquerque, New Mexico, June 1962.

Abstract: Describes model of human error consisting of 2 cross-cutting systems of classification. Error frequencies within each mode are combined with system parameters to produce quantitative models.

Schwimmer, M.J., "A Personnel Study of Licensed U.S. Merchant Marine Officers," National Maritime Research Center, Kings Point, New York, June 1973.

Abstract: Studies were made of occupational environment and trends, including career and life style analysis, and the creation of a personal injury data bank. Objective of the study was to increase productivity and efficiency of personnel who sail American flag ships while increasing job satisfaction and reducing accidents.

Sherar, M.G., "Shipping Out: A Sociological Study of the American Merchant Seaman," Cornell Maritime Press, Cambridge, Maryland, 1973.

Abstract: Presents psychological and sociological profile of seamen--why men choose the sea, the "bar scene," marriage, women in seamen's lives, alcoholism, myths, social system of the occupation, health.

Shimberg, B., "Survey of Procedures Used by the U.S. Coast Guard for Licensing Deck and Engineering Officers in the U.S. Merchant Marine," Educational Testing Center, Princeton, New Jersey, February 1969.

Abstract: Historical review of licensing procedures and review of current examination practices. Discussion of the licensing structure includes a proposed license structure for deck officers and engineering personnel. Suggestions for effecting change in the short- and long-term are made.

Silverlead, A., "Ship Behaviour at Sea and Its Study in the Laboratory," National Physical Laboratory, Teddington, Middlesex, England, 1968.

Abstract: Discussion of the way in which the scientific method has been introduced and developed during the past 100 years to provide knowledge about ship's behavior at sea.

Sleight, R.B. and K.G. Cook, "Problems in Occupational Health and Safety: A Critical Review of Select Worker Physical and Psychological Factors," Century Research Corp., Arlington, Virginia, 1973.

Abstract: Summary reviews of studies relating the effects on worker safety and health of personal characteristics of age, sex, physical work capacity, alcohol and drug effects, fatigue, etc.

Slovic, P., B. Fishkoff and S. Lichtenstein, "Cognitive Processes and Societal Risk-Taking," to be published in Carroll and Payne, Cognitive and Societal Behavior, Lawrence Erlbaum Associates, Potomac, Maryland, 1976.

Abstract: Three questions discussed: what are some basic policy issues regarding societal risk, what do psychologists know that is relevant, and what more do we need to know and how might we acquire this knowledge?

Sperry Piedmont Co., "Lookout Assist Device Feasibility Studies, Volume I: Human Factors Collision Statistics, Economic Factors, Operations Research, Sensor Techniques," Charlottesville, Virginia, August 1965.

Abstract: Study of human factors and collision statistics showing that a proximity warning device would fit into the traditional mode of ship operation, and should improve chances of avoiding collisions. Other areas discussed include the degree of danger assessment and the need for better maneuvering plan data.

Sprintzer, A., "Trade Union Sponsored Occupational Training in the U.S. Maritime Industry: The Upgrading and Retraining Program of the National Maritime Union," New York School of Industry and Labor Relations, Ithaca, New York, June 1971.

Abstract: Study examines the objectives, structure, functions and results of the NMU upgrading and retraining program, and attempts to analyze their determinants.

Stewart, J.P., "Bridge Design in Relation to Casualties," Tanker and Bulk Carrier, Terminus Publications, Kent, England, April 1973.

Abstract: Intends to show that actual design of a navigation bridge, along with its associated equipment has been a contributing factor in marine collisions and groundings. Specific problems related to particular categories of bridge equipment are discussed.

Stewart, J.P., "Development of the Navigating Bridge," Tank and Bulk Carrier, March 1973.

Abstract: Evolution of the structure of the ship's bridge, and discussion of basic instruments and their functions.

Stroud, J.M., "The Fine Structure of Psychological Time," Naval Electronics Laboratory Center, San Diego, California, October 1955.

Abstract: Study of information handling capacities, transfer function and servo characteristics of man as related to control operations, information processing, and monitoring aspects of electronic equipment. Investigation of how man handles time when he converts time-varying inputs into time-varying outputs.

Sun Oil Company, "Analyses of World Tank Ship Fleet," St. Davids, Pennsylvania, December 1973 and 1974.

Abstract: Inventory of world tank ship by fleet, tonnage, capacity, age, draft. Basic tank ship economics and statistical tabulations.

Tarrants, W.E., "The Evaluation of Safety Program Effectiveness," Department of Transportation, NHTSA, 1972.

Abstract: Discussion of ideal characteristics of performance criteria measures.

Thorndike, R.L., "The Human Factor in Accidents with Special Reference to Aircraft Accidents," USAF School of Aviation Medicine, Randolph Field, Texas, February 1951.

Abstract: Nature and background of the problem of aircraft accidents, reporting and coding of accidents, accident proneness, prediction of accident proneness, accidents as related to temporary attributes, accidents in relation to training and experience, and situational factors in accident causation.

Toronto, R.S., "A General Systems Model for the Analysis of Organizational Change," Behavioral Science, Volume 20, 1975.

Abstract: Describes a framework, methods, and three hypotheses for evaluating system change. Hypotheses were tested and methods and procedures associated with each are discussed.

Transport and Technical Publications, "Training Courses for LNG Carrier Staff," Shipbuilding and Shipping Record, presented at Second LNG Transportation Conference, October 23-24, 1973, London, England.

Abstract: Development of gas transportation courses is described. Objective of an LNG training scheme is duscussed, along with detailed descriptions of course contents.

Transport and Technical Publications, "Incentives for Safety," Shipbuilding and Shipping Record, London, England, May 1970.

Abstract: The hazards to shipping posed by undermanning and inadequately trained crews are discussed, along with proposed remedies and recommendations.

Transport and Technical Publications, "Uglands Project Ships Scheme, Shipbuilding and Shipping Record, London, England, June 1970.

Abstract: Discussion of the Uglands Rederi project. An attempt to hand responsibility to ship officers to overcome frustration due to lack of meaningful tasks was made. Results showed increased technical standards, reduction of expenses and increased interest and morale.

Department of Transportation, "Collisions Within the Navigable Waters of the United States," National Transportation Safety Board, February 1972.

Abstract: Evaluation of causes and potential results of collisions in the navigable waters of the U.S. based on casualty reports of major collisions for which NTSB determined the probable causes. Methods of preventing collisions and minimizing the potential losses resulting from collisions are discussed.

Tuttle, T., W.T. Liggett and N.E. Killian, "Psychological Behavioral Strategy for Accident Control: Development of Behavioral Safety Guidelines," Part I, Behavioral Safety Center, Westinghouse Electric Corp., Columbia, Maryland, December 1973.

Abstract: Discussion of rationale underlying a behavioral approach to accident control and presents guidelines for the application of behavioral science to industrial safety problems.

Tuttle, T., W.T. Liggett and N.E. Killian, "Psychological Behavioral Strategies for Accident Control: A System for Diagnosis and Intervention," Part II, Behavioral Safety Center, Westinghouse Electric Corp., Columbia, Maryland, December 1974.

Abstract: Traditional safety diagnostic procedures are categorized and explained briefly. A procedure for safety analysis is outlined which takes into consideration both traditional safety or hazard approaches and organizational analysis or diagnosis, and recommendations are made.

United States Salvage Association, Inc., "Analytical Data on Marine Accidents Pertaining to Ocean Vessels with 5000 Tons Displacement and Over," New York, New York, December 1958.

Abstract: Delineates accident causation factors and enumerates extent of damage sustained by conventionally-powered vessels.

Vallance, T.R., A.S. Glickman and J.N. Vasilas, "Critical Incidents in Junior Officer Duties Aboard Destroyer-Type Vessels," American Institute for Research, April 1954.

Abstract: Development of a set of critical performance requirements for junior officers. Data collected from group interviews; 1700 critical incidents were organized into 102 categories.

Wiederkehr, R.R.V., "Forecast of 1970-1985 World Shipping," SACLANT ASW Research Centre, NATO, La Spazia, Italy, September 1971.

Abstract: Defines classes of merchant ships as tankers, bulk carriers, container ships, other cargo ships. Describes trade carried by each, productivity of world merchant fleet, and growth and distribution of world merchant fleet.

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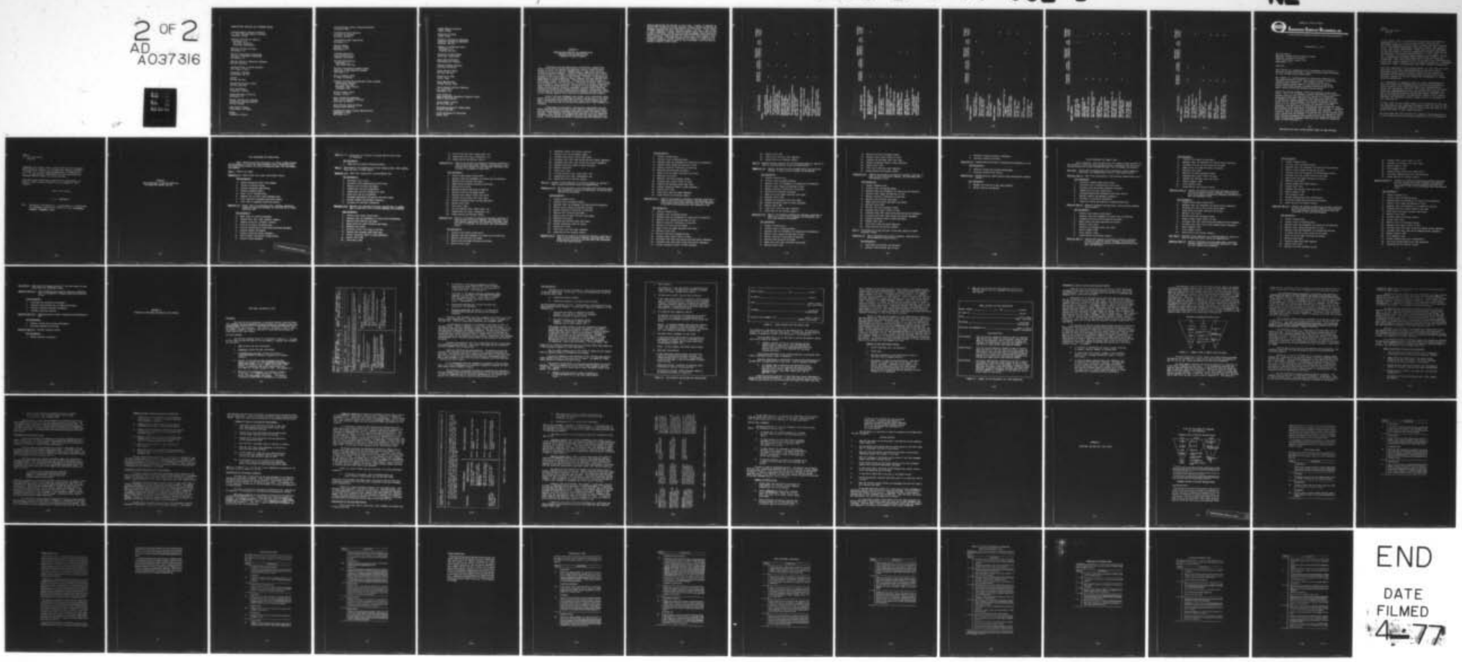

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ORGANIZATIONS CONTACTED FOR LITERATURE REVIEW

Aerospace Medical Research Laboratory
U.S. Naval Aerospace Medical Institute
Pensacola, Florida

American Institutes for Research
  Washington, D.C.
  Palo Alto, California
  Pittsburgh, Pennsylvania

American Petroleum Institute
Washington, D.C.

American Psychological Association
Division of Engineering Psychology
Washington, D.C.

American Society of Mechanical Engineers
New York, New York

American Society of Safety Engineers
Park Ridge, Illinois

University of Buffalo
Cheektowaga, New York

CALSPAN
Buffalo, New York

Engineering Societies Library
New York, New York

Essex Corporation
Alexandria, Virginia

George Washington University
Washington, D.C.

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia

Human Factors Society
Santa Monica, California

HumRRO
Alexandria, Virginia

Inland Waterways Safety & Health Association
Cincinnati, Ohio

Institute for Social Research
University of Michigan
Ann Arbor, Michigan

International Labor Organization
Washington, D.C.

Japanese Embassy
Ministry of Labor
Washington, D.C.

Lockheed Corporation
Ocean Systems Division
Sunnyvale, California

Maritime Administration
  Washington, D.C.
  Kings Point, New York

Maritime Transportation Research Board
Commission of Sociotechnical Systems
Washington, D.C.

Missile Research Center
Pt. Mogu, California

National Institute for Occupational Safety & Health
  Gaithersburg, Maryland
  Salt Lake City, Utah
  Morgantown, West Virginia
  Cincinnati, Ohio

National Safety Council
Chicago, Illinois

Naval Electronics Laboratory
Human Factors Technology Division
San Diego, California

North Carolina State University
Raleigh, North Carolina

Occupational Safety & Health Administration
Department of Labor
Washington, D.C.

Oregon Research Institute
Eugene, Oregon

University of Oregon
Eugene, Oregon

Rochester Institute of Technology
Industrial Engineering Department
Rochester, New York

Seafarer's International Union
Washington, D.C.
Brooklyn, New York

University of South Dakota
Vermillion, South Dakota

Sperry Rand Corporation
Charlottesville, Virginia

Stanford Research Institute
Palo Alto, California

Tanker Advisory Center
New York, New York

University of Texas
Austin, Texas

Texas A&M University
College Station, Texas

Towing Industry Advisory Committee
U.S. Coast Guard
Washington, D.C.

Tufts University
Human Engineering Information & Analysis Center
Medford, Massachusetts

United Seamen's Service
New York, New York

Westinghouse Behavioral Safety Center
Columbia, Maryland

Wright Patterson Air Force Base
Dayton, Ohio

APPENDIX B

ORGANIZATIONS CONTACTED FOR INFORMATION ON OPERATIONS FOR TASK ANALYSIS AND EXAMPLE OF LETTER OF CONTACT

Individuals from the organizations, associations, companies and schools listed in this appendix provided much valuable information which we used as a basis for the task statements and, in some cases, served as reviews of the task statements. Chevron Shipping Company and Exxon Corporation contributed full volumes of operating procedures which proved to be invaluable in the initial stages of task writing. Personnel in the operations departments of various towboat and tanker companies also gave detailed information based on years of experience. Those persons with whom we spoke in each company, school, organization, etc., had served as masters, deck officers, or port captains, and, as such, were able to provide first-hand information on tasks required of bridge personnel. As batches of task statements were completed, we sent them for review to three major training schools (Maritime Institute of Technology and Graduate Studies, Seafarer's International Union of North America, and National Maritime Union Upgrading and Retraining School) and two shipping companies (Dixie Carriers and Keystone Shipping Company).

Once all the task statements were written, actual observation aboard vessels by the study team allowed them to check on the accuracy of the statements. Observations of and discussion with crews of three towboats and one deep draft vessel provided on-site verification/accuracy of task statement information.

Listed below are the schools, associations, organizations and companies contacted during the course of this study for information relating to the tasks and operational procedures performed by tanker and towboat bridge personnel. Most companies and organizations were able to give us background information about the type of equipment and facilities they owned and/or operated. This information was helpful in selecting operating companies which

would be appropriate for and open to site visits. A number of companies described their on-the-job training programs, although few had any written documentation available or which they were willing to provide. A small number of tanker companies had formal operations manuals, but, again, were not open to public inspection. However, Chevron Shipping Company, Exxon Corporation, and Mobile Oil Corporation did make available information relating to operational procedures. Some companies and organizations, while unable to give us specific verbal or written information, were helpful in referring us to available information sources based on their knowledge of policies and procedures of others in their field.

Sources Contacted	Background Information	Training Information	Operations/ Procedures Information	Site Visits	Reference To Other Sources
SCHOOLS					
Harry Lundeberg School Seafarers International Union of North America Piney Point, Maryland	●	●			
Maritime Institute of Technology and Graduate Studies 5700 Hammonds Ferry Road Linthicum Heights, Maryland		●		●	
National River Academy Education Committee Missouri Barge Company 500 Aquansi Street Cape Girardeau, Missouri	●	●			
National Maritime Union Upgrading and Retraining School 346 West 17th Street New York, New York	●				●
ASSOCIATIONS, RESEARCH ORGANIZATIONS					
American Institute of Merchant Shipping 1625 K Street, N.W. Washington, D.C.	●				●
Maritime Transportation Research Board National Academy of Sciences 2102 Constitution Avenue, N.W. Washington, D.C.	●				

Sources Contacted	Background Information	Training Information	Operations/ Procedures Information	Site Visits	Reference To Other Sources
ASSOCIATIONS, RESEARCH ORGANIZATIONS					
American Waterway Operators 1600 Wilson Boulevard Arlington, Virginia	●				●
TANKER COMPANIES					
Amoco International Oil Company 555 Fifth Avenue New York, New York	●				
Atlantic-Richfield Company (ARCO) Products Division Marine Terminal - Fort Miffin P.O. Box 7709 Philadelphia, Pennsylvania	●				
Chevron Shipping Company 555 Market Street San Francisco, California			●		
Exxon Corporation 1251 Avenue of the Americas New York, New York			●		
Gulf Oil Trading Marine Transportation Division #2 Bala-Cynwyd Plaza Bala-Cynwyd, Pennsylvania	●				

Sources Contacted	Background Information	Training Information	Operations/ Procedures Information	Site Visits	Reference To Other Sources
TANKER COMPANIES					
Keystone Shipping Co. Philadelphia, Pennsylvania				●	
Mobile Oil Corporation 150 East 42nd Street New York, New York			●		
Texaco, Inc. 603 West Division Street Dover, Delaware	●	●			
TOWBOAT COMPANIES					
Alter Towing Company Cincinnati, Ohio					●
American Commercial Barge Line Company P.O. Box 610 1701 East Market Street Jeffersonville, Indiana					●
Ashland Oil Company P.O. Box 391 Ashland, Kentucky					●
Chotin New Orleans, Louisiana	●		●		
Dixie Carriers, Inc. P.O. Box 248 Harvey, Louisiana				●	

Sources Contacted	Background Information	Training Information	Operations/ Procedures Information	Site Visits	Reference To Other Sources
TOWBOAT COMPANIES					
Dixie Carriers, Inc. 1616 West Loop South Houston, Texas				●	
Exxon Corporation USA Marine Department P.O. Box 411 Baton Rouge, Louisiana	●				
Gulf Mississippi Marine Corp. New Orleans, Louisiana	●				●
Ingram Barge 4100 Shell Square Baton Rouge, Louisiana	●				●
Mobile Oil Corporation 150 E. 42nd Street New York, New York	●				●
National Marine Service, Inc. 100 W. 10th Street Wilmington, Delaware			●	●	
National Marine Service, Inc. 1750 Brentwood Blvd. St. Louis, Missouri	●				●
Nilo Barge Company 112 N. 4th Street St. Louis, Missouri					●

Sources Contacted	Background Information	Training Information	Operations/ Procedures Information	Site Visits	Reference To Other Sources
TOWBOAT COMPANIES					
Ohio Barge Line, Inc. P.O. Box 126 Dravosburg, Pennsylvania	●	●			
Oil Transport Company, Inc. P.O. Box 52708 New Orleans, Louisiana					●
Sabine Towing and Transportation Company, Inc. P.O1 Box 1528 Port Arthur, Texas	●	●			
Southern Towing Memphis, Tennessee	●				●
Texaco, Inc. 603 West Division Street Dover, Delaware	●				●
New York Marine Office 2100 Hunters Point Office Long Island City, New York	●				●

EXAMPLE OF LETTER OF CONTACT

ECO ENGINEERING COMPUTER OPTECNOMICS, INC.

Systems Analysts for Engineers, Economists and Environmental Scientists

September 15, 1975

Mr. Len Bassil
Maritime Transportation Research Board
National Academy of Sciences
2102 Constitution Avenue, N.W.
Washington, D.C.

Dear Len:

This letter is a follow-up to our telephone conversation in which we briefly discussed a research project being conducted for the United States Coast Guard.

Our company is a subcontractor to Operations Research Inc., the prime contractor under Coast Guard contract CG-41903-A, "Human Factors Research". The research project is a broad-gauged program aimed at the reduction of merchant marine casualties through increased understanding of the human factors affecting merchant marine safety.

Within the overall program, there are presently three major tasks. Task I is to develop a general methodology to ascertain minimum training and qualification levels for occupations associated with newly emerging technologies and specifically, to determine training procedures and qualifications for LNG Cargo Officer, LNG Tankerman, and Nuclear Propulsion Engineer. Task II is to conduct a functional job analysis on bridge personnel with the intent of identifying those aspects of human performance which might best be improved upon in order to minimize the occurrence of collisions, groundings, and rammings. (In this instance, both an oceangoing ship system and a river towboat-barge array system will be studied.) Task III will be similar to Task I with training procedures and qualifications being developed for cargo officers and tankermen handling bulk chemicals regulated under 46 CFR Subchapter O.

505 Burning Tree Drive, Arnold, Maryland 21012, Tel: (301) 757-3245

In all three tasks, the Functional Job Analysis methodology developed by Dr. S.A. Fine of the Upjohn Institute for Employment Research will be used to conduct the task analyses (i.e., performance standards, training content, and adaptive skills) for tasks identified. These task analyses developed by the ORI team will then be augmented by direct observations and personal interviews where possible. In all cases, it is our intention to circulate these analyses for comments insofar as is reasonable and practicable within time and resources restraints. The circulation will be to people and organizations within the marine industry such as shipping companies, independent operators, labor, shipbuilding, and other related technologies.

Upon the completion of the review phase, it will then be incumbent upon us to make recommendations to the Coast Guard concerning qualifications and training for the respective licenses and documents including initial certification and periodic renewal having due regard for differences in vessel size and operations.

It is important to emphasize that our final deliverables to the Coast Guard are recommendations and do not necessarily infer ultimate Coast Guard acceptance and implementation within the regulatory process. The Coast Guard will obviously weigh our recommendations and then proceed to implement any that they deem appropriate through the normal federal rule-making procedures which include public notice in the Federal Register and subsequent public comment prior to issuance of any regulations.

At this time, we are simply asking you to provide us with any job descriptions and training literature that are used by your organization by September 30th so that we may use them in our background work in task identification.

We also hope that this letter will serve to fully apprise you of our efforts and to gain your cooperation in this endeavor.

Commander Ben Joyce, Chief, Vessel Manning and Personnel Qualifications Branch, of The Merchant Vessel Personnel Division, U.S. Coast Guard Headquarters in Washington, D.C., is the project representative from the Office of Merchant Marine Safety for this contract.

Both the Coast Guard and ourselves will appreciate any efforts which you may extend to us in behalf of this project.

Very truly yours,

J. D. PORRICELLI

Encl: Functional Job Analysis: An Approach to a Technology for Manpower Planning by Sidney A. Fine, Personnel Journal, November, 1974.

APPENDIX C

TASK DESIGNATORS, BY GOAL AND OBJECTIVE, FOR TANKER AND TOWBOAT ANALYSES

TASK DESIGNATORS FOR TANKER TASKS

Goals, objectives and task descriptors for tanker bridge personnel for the purpose of controlling vessel movements along a designated track while maintaining schedule and without endangering human life, environment and property.

Goal I: Prepare for voyage

Objective I.A: Select route, plot track, and estimate timing.

Task Designators:

1. Selects navigation charts from stowage.
2. Corrects navigation charts.
3. Corrects navigation publications.
4. Studies navigation charts
5. Draws line of intended track.
6. Computes set and drift along intended track.
7. Plots location of expected significant events.
8. Lists times of expected significant events.

Objective I.B: Ensure that all navigational aids, steering, propulsion system and associated equipment are available and in proper operating order.

Task Designators:

1. Makes ready all plotting equipment.
2. Inspects gyro, RDF, radar, magnetic compass.
3. Inspects binoculars, alidades, sextants.
4. Turns on electronic navigation gear.
5. Verifies functioning of interfacing engineroom equipment.
6. Inspects weather instruments.
7. Inspects lights and signal equipment.
8. Tests internal and external communications.
9. Inspects safety equipment.

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Objective I.C: Ensure that all required pre-voyage administrative tasks are completed.

Task Designators

1. Identifies and submits shipping documents.

Goal II: Berth/unberth ship expeditiously without damaging wharf, pier, mooring buoy, own ship, or other vessels.

Objective II.A: Make final preparations to berth/unberth ship.

Task Designators:

1. Ascertains ship's draft.
2. Ascertains port's characteristics and rules.
3. Monitors wind direction and speed.
4. Communicates with port authorities.
5. Communicates mooring information to crew.
6. Reads pilot and tug information.
7. Exchanges maneuvering information with other ships.
8. Reviews standard and emergency maneuvers.
9. Evaluates all pertinent information.

Objective II.B: Maneuver ship into/away from berth, mooring buoy, or anchorage, as applicable, while avoiding rammings, and groundings.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Monitors wind direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Determines anchor drop range or bearing.
7. Examines and evaluates total data input.
8. Conveys navigation orders to other personnel.
9. Adjusts ship's RPM.
10. Turns ship's helm.

11. Utilizes mooring lines, anchor chain, etc.
12. Communicates with tugs, linehandlers, etc.
13. Sounds whistle and displays signals.

Objective II.C: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering ship into/away from berth, mooring buoy, or anchorage, as applicable.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Monitors wind direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Determines anchor drop range or bearing.
7. Monitors collision avoidance system.
8. Assesses other vessel traffic near berth.
9. Examines and evaluates total data input.
10. Conveys navigation orders to other personnel.
11. Adjusts ship's RPM.
12. Turns ship's helm.
13. Utilizes mooring lines, anchor chain, etc.
14. Communicates with tugs, linehandlers, etc.
15. Sounds whistle and displays signals.

Objective II.D: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering ship into/away from berth, mooring buoy, or anchorage, as applicable, when some emergency arises.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Monitors wind direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.

6. Determines anchor drop range or bearing.
7. Monitors collision avoidance system.
8. Assesses other vessel traffic near berth.
9. Evaluates total data input during non-ship control emergency.
10. Evaluates total data input during ship-control emergency.
11. Conveys navigation orders to other personnel.
12. Adjusts ship's RPM.
13. Turns ship's helm.
14. Utilizes mooring lines, anchor chain, etc.
15. Communicates with tugs, linehandlers, etc.
16. Sounds whistle and displays signals.

Goal III: Navigate through (maneuver in) restricted waters as required in order to reach destination safely and expeditiously.

Objective III.A: Maintain designated track and speed within restricted waterway, modifying as required by conditions, in order to avoid rammings and groundings.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Examines and evaluates total data input.
10. Conveys navigation orders to others.
11. Adjusts ship's RPM.
12. Turns ship's helm and reads compasses.
13. Sounds whistle and displays signals.

Objective III.B: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maintaining position within the limitations of the restricted waterway.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Monitors collision avoidance system.
10. Assesses other vessel traffic in area.
11. Examines and evaluates total data input.
12. Conveys navigation orders to other personnel.
13. Adjusts ship's RPM.
14. Turns ship's helm and reads compasses.
15. Sounds whistle and displays signals.

Objective III.C: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings while simultaneously maintaining position within the limitations of the restricted waterway when some emergency arises.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Monitors collision avoidance system.
10. Assesses other vessel traffic in area.
11. Evaluates total data input during non-ship-control emergency.
12. Evaluates total data input during ship-control emergency.
13. Conveys navigation orders to other personnel.

14. Adjusts ship's RPM.
15. Turns ship's helm and reads compasses.
16. Sounds whistle and displays signals.

Goal IV: Navigate through (maneuver in) non-restricted waters as required in order to reach destination safely and expeditiously.

Objective IV.A: Maintain designated track and speed within non-restricted waterway in order to avoid rammings and groundings.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Examines and evaluates total data input.
10. Conveys navigation orders to other personnel.
11. Adjusts ship's RPM.
12. Turns ship's helm and reads compasses.
13. Sounds whistle and displays signals.

Objective IV.B: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings (non-restricted waterway environment).

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.

9. Monitors collision avoidance system.
10. Assesses other vessel traffic in area.
11. Examines and evaluates total data input.
12. Conveys navigation orders to other personnel.
13. Adjusts ship's RPM.
14. Turns ship's helm and reads compasses.
15. Sounds whistle and displays signals.

<u>Objective IV.C</u>: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings when some emergency arises.

<u>Task Designators</u>:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Obtains electronic indications of position.
6. Monitors wind direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Monitors collision avoidance system.
10. Assesses other vessel traffic in area.
11. Evaluates total data input during non-ship-control emergency.
12. Evaluates total data input during ship-control emergency.
13. Conveys navigation orders to other personnel.
14. Adjusts ship's RFM.
15. Turns ship's helm and reads compasses.
16. Sounds whistle and displays signals.

<u>Goal V</u>: Train/supervise bridge personnel in the safe conduct of vessel throughout voyage.

<u>Objective V.A</u>: Impart knowledge about specific features, characteristics and procedures of vessel control.

<u>Task Designators</u>:

1. Interviews and evaluates new personnel.
2. Conducts indoctrination tour of ship.

3. Maintains standard reference information.

4. Provides on-the-job training.

Objective V.B: Examine/evaluate trainee's knowledge and performance on site.

Task Designators:

1. Observes trainee and discusses performance.

2. Discusses problems with trainee.

Objective V.C: Perform necessary administrative tasks and maintain required records.

Task Designators:

1. Manages and organizes bridge team personnel.

2. Records required information.

TASK DESIGNATORS FOR TOWBOAT TASKS

Goals, objectives, and task descriptors for towboat bridge personnel for the purpose of controlling vessel movements along a designated track while maintaining schedule and without endangering human life, environment and property.

Goal TOW-I: Berth/unberth towboat-barge array expeditiously without damaging wharf/pier, own towboat-barge array, or other nearby vessels.

Objective TOW-I.A: Make final preparations to berth/unberth towboat-barge array.

Task Designators:

1. Ascertains towboat-barge array's draft.
2. Ascertains port's characteristics and rules.
3. Estimates wind and current direction and speed.
4. Communicates with port authorities.
5. Exchanges maneuvering information with other vessels.
6. Reviews standard and emergency maneuvers.
7. Evaluates all pertinent information.
8. Supervises making and breaking of towboat-barge array.

Objective TOW-I.B: Maneuver into/away from wharf/pier, while avoiding rammings and groundings.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Examines and evaluates total data input.
7. Adjust towboat's RPM.
8. Turns towboat's helm.
9. Sounds whistle and displays signals.

Objective TOW-I.C: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering towboat-barge array into/away from wharf/pier.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Monitors collision avoidance system.
7. Assesses other vessel traffic in area.
8. Examines and evaluates total data input.
9. Adjusts towboat's RPM.
10. Turns towboat's helm.
11. Sounds whistle and displays signals.

Objective TOW-I.D: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings, while simultaneously maneuvering into/away from wharf/pier when some emergency arises.

Task Designators:

1. Visually scans waters around berth.
2. Operates radar and fathometer for hazard and aid detection.
3. Estimates wind and current direction and speed.
4. Reads course and speed indicators and alarms.
5. Monitors voice radio.
6. Monitors collision avoidance system.
7. Assesses other vessel traffic in area.
8. Evaluates total data input during non-towboat-control emergency.
9. Evaluates total data input during towboat-control emergency.
10. Adjust towboat's RPM.
11. Turns towboat's helm.
12. Sounds whistle and displays signals.

Goal TOW-II: Navigate through (maneuver in) restricted waters as required in order to reach destination safely and expeditiously.

Objective TOW-II.A: Maintain designated track and speed within restricted waterway, modifying as required by conditions in order to avoid rammings and groundings.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Operates radar and fathometer for navigational position.
6. Estimates wind and current direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Studies bridges and bridge supports.
10. Studies canal locks.
11. Examines and evaluates total data input.
12. Adjusts towboat's RPM.
13. Turns towboat's helm.
14. Grounds towboat-barge array intentionally.
15. Extricates towboat-barge array from grounding.
16. Sounds whistle and displays signals.

Objective TOW-II.B: Identify and respond to potentially hazardous conditions in order to avoid collisions, rammings, and groundings while simultaneously maintaining position within the limitations of the restricted waterway.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Operates radar and fathometer for navigational position.
6. Estimates wind and current direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Studies bridges and bridge supports.
10. Studies canal locks.
11. Monitors collision avoidance system.

12. Assesses other vessel traffic in area.
13. Examines and evaluates total data input.
14. Adjusts towboat's RPM.
15. Turns towboat's helm.
16. Grounds towboat-barge array intentionally.
17. Extricates towboat-barge array from grounding.
18. Sounds whistle and displays signals.

Objective TOW-II.C: Identify and respond to potentially hazardous conditions in crder to avoid collisions, rammings, and groundings while simultaneously maintaining position within the limitations of the restricted waterway when some emergency arises.

Task Designators:

1. Studies intended track.
2. Visually scans surrounding waters.
3. Operates radar and fathometer for hazard and aid detection.
4. Obtains visual ranges and bearings to aids.
5. Operates radar and fathometer for navigational position.
6. Estimates wind and current direction and speed.
7. Reads course and speed indicators and alarms.
8. Monitors voice radio.
9. Studies bridges and bridge supports.
10. Studies canal locks.
11. Monitors collision avoidance system.
12. Assesses other vessel traffic in area.
13. Evaluates total data input during non-towboat-control emergency.
14. Evaluates total data input during towboat-control emergency.
15. Adjusts towboat's RPM.
16. Turns towboat's helm.
17. Grounds towboat-barge array intentionally.
18. Extricates towboat-barge array from groundings.
19. Sounds whistle and displays signals.

Goal TOW-III: Supervise/train towboat personnel in the safe conduct of towboat-barge array throughout voyage.

Objective TOW-III.A: Impart knowledge about specific features, characteristics, and procedures of towboat-barge array controllability.

Task Designators:

1. Interviews and evaluates new personnel.
2. Conducts indoctrination tour of towboat and barges.
3. Maintains standard reference information.
4. Provides on-the-job training.

Objective TOW-III.B: Examine/evaluate trainee's knowledge and performance on site.

Task Designators:

1. Observes trainee and discusses performance.
2. Discusses problems with trainee.

Objective TOW-III.C: Maintain required records.

Task Designators:

1. Records required information.

APPENDIX D

OVERVIEW OF FUNCTIONAL JOB ANALYSIS (FJA) METHOD

FUNCTIONAL JOB ANALYSIS (FJA)

BACKGROUND

This section on FJA procedures is excerpted from ORI Technical Report 1012, Handbook for the Development of Qualifications for Personnel in New Technology Systems, February 1976. It describes the methods and guidelines used to construct FJA task statements. The content of the material used in some of the example statements relates to functions of cargo handling personnel on Liquid Natural Gas (LNG) tankers.

FJA TASK STATEMENT

The FJA task statement format is illustrated in Figure D.1. As shown in this figure through the means of circled numbers, a complete task statement has nine parts:

1. Goal to which the task contributes.

2. Objective to which the task contributes.

3. A description of the task, written according to a prescribed format to include a standard set of content elements.

4. Measures of the level of the involvement with data, people, and things, i.e., the complexity of the worker's action with respect to data, people, and things. Complexity is determined from scaled descriptions that have numerical ratings assigned to them. (See Appendix E.)

5. Measures of the orientation of the worker's function in the task, i.e., extent to which it involves the worker with data, people, and things. The extent of involvement of each kind is expressed as a percentage.

TASK CODE: CO-II.A.1

WORKER FUNCTION LEVEL AND ORIENTATION						6 WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
4 DATA	5 %	4 PEOPLE	5 %	4 THINGS	5 %		7 REASONING	7 MATH	7 LANGUAGE
38	65	2	5	1A	30	3	3	1	2

TASK CODE: CO-II.A.1 **GOAL:** To discharge LNG safely. 1

OBJECTIVE: 2 To place the vessel in a condition suitable for the discharging of LNG.

TASK: 3 Periodically, visually inspect and check the mooring system in order to ensure that the vessel is moored in accordance with the mooring arrangement diagrams for the specific loading terminal, using your own judgment as to anticipated wind and sea conditions and known strength and conditions of the mooring lines.

8 PERFORMANCE STANDARDS	9 TRAINING CONTENT
<u>Descriptive</u>: • Mooring lines are taut without any line being over-stressed. • "Badly worn" mooring lines are not used. • Safety considerations are maximized. <u>Numerical</u>: • In 100% of the cases, the vessel is moored in accordance with the mooring arrangement diagram. • The mooring lines are inspected at least once every three (3) hours. • In 100% of the cases, the vessel's mooring system withstands forces caused by sudden and/or extreme changes in wind/sea conditions.	<u>Functional</u>: • How to evaluate by experience, weather report, or barometric pressure, the forces on a moored ship with respect to wind/sea conditions. • How to compensate for "aged" or "slightly worn" mooring lines. • How to recognize the different types of mooring lines as well as their individual capabilities and limitations. • How to read mooring arrangement diagrams. <u>Specific</u>: • Knowledge of the vessel's mooring lines. • Knowledge of the specific mooring arrangement diagram for specific loading terminal.

FIGURE D.1. EXAMPLE OF AN FJA TASK STATEMENT

6. An indicator of the level of complexity of the instructions the worker must follow. Level of instructions is also given a numerical rating according to a complexity scale. (See Appendix E.)

7. Indicators of the general education development (GED) required to do the task, i.e., the level of language, math, and reasoning skills. These levels are also given numerical ratings according to complexity scales. (See Appendix E.)

8. Performance standards-the criteria by which performance will be evaluated.

9. Training content-what the worker has to know and be trained to do to perform the task to the standards indicated.

The terms "task statement" and "task statement form" refer to all nine parts or their documentation. "Task description" is the verbal statement of the task only. Figure D.1 shows how a completed task statement looks.

The development of each part is initiated in the order in which it has been listed. However, feedback is a basic part of the FJA process. As the analyst considers task orientation, he may realize that his writeup of the task description emphasizes the wrong orientation. The task may be primarily an interaction with people but, because filling out a form is involved, the analyst may have written the task so that it sounds like a data oriented task. The scale ratings for the complexity of task content, instructions, and language/reasoning/math skills similarly provide checks on the accuracy of the task description.

The goals and objectives will have already been defined in the process of delineating system functions. Those goals and objectives are recorded on the task statement forms as appropriate.

Tasks are identified for each objective. The analyst now uses the structure and language prescribed by FJA to write a complete description of each task. The analysis goes on to complete the other parts of the task statement in turn, using each as a check on the veracity of the preceding parts. When a task statement is well done, the parts complement each other-they make a sensible and logical whole.

It is recommended that task statements be prepared in sets by objective. It is also recommended that a complete statement be prepared for each task before another statement is begun.

The processes of describing the tasks and completing the remainder of the task statement form are explained individually in the following paragraphs. It should be remembered that in the actual performance of this process, the analyst will freely look back to check and adjust preceding parts.

Task Description

The quality of the task statement as a whole flows from the quality of the task description. Consistency, clarity and comparability of task descriptions result from:

- Controlled content elements
- Controlled language to describe content elements.

The FJA procedure provides for both. The developers of FJA have this to say about required content elements: "The two most important elements of a task statement are:

1. The action the worker is expected to perform. Example: Asks questions, listens to responses, and writes answers on standard forms.
2. The result expected of the worker action. Example: To record basic identifying information such as name, address, etc."

"The worker action(s) phrase in the task description represents the worker's activity as concretely as possible. The result phrase describes explicitly what his action is expected to produce or what gets done, which identifies the worker's concrete contribution to a process or work system objective. Although action and result are the two most critical elements in a task description, and can be thought of as the skeleton of a task, the description must include additional items of information to communicate clearly and consistently." (Fine and Wiley, 1971)

Figure D.2 is a checklist excerpted from Fine and Wiley (1971) that states all of the information needed in a task description.

Use of a model sentence such as that shown in Figure D.3 will ensure that all necessary items of information are included.

The use of language is also important in FJA. Writing task descriptions requires practice in the precise use of terms. The reader of a task should be able to visualize the task clearly.

The choice of action words in a task description affects its clarity the most. There is a tendency to use end result verbs instead of explicit action verbs. Whenever an end result verb is used, the worker action is obscured. For example:

- (Worker), trim the vessel in order to position it in the trim condition for LNG cargo loading operations...

1. Who? (Subject)

The subject of a task description is understood to be simply "worker." The description contains no subject since it is always assumed to be "worker."

2. Performs what action? (Action Verb and Object)

A task description requires a concrete, explicit action verb. Verbs which point to a process (such as develops, prepares, interviews counsels, evaluates and assesses) should be avoided or used only to designate broad processes, methods, or techniques which are then broken down into explicit, discrete action verbs.

3. To accomplish what immediate results?

The purpose of the action performed must be explicit so that (1) its relation to a system objective is clear and (2) performance standards for the worker can be set.

Result: To determine whether they have been securely joined, for transfer of LNG from terminal to ship tanks. The objective to which this result is directed is: Safe loading of LNG within scheduled time.

4. With what tools, equipment, or work aids?

A task description should identify the tangible instrumentation a worker uses as he performs a task: for example, telephone, pencil/paper, checklists, written guides, wrench, etc.

Tools: In this example, the worker uses no tools.

5. Upon what instructions?

A task description should reflect the nature and source of instructions the worker receives. It should indicate what in the task is prescribed by a superior and what is left to the worker's discretion or choice.

Prescribed content: According to equipment specifications for transfer line connections.

Discretionary content: Exercising some leeway as to sequence and timing of inspection.

FIGURE D.2. FJA CHECKLIST FOR WRITING TASK DESCRIPTIONS

Worker, please ____________, __________, and ______________	(action)
In order to ____	(result)
Using ____	(tools, equipment, work aids)
Following ____	(prescribed instructions)
Using your own judgment as to ____________________	(what is left to worker's discretion)

FIGURE D.3. MODEL SENTENCE FOR TASK DESCRIPTIONS

Trim condition is the desired result of the worker action. The result was turned into a verb for the task description. It might just as well read "Do whatever is necessary in order to put the vessel in trim condition..."

The task description can be rewritten to clarify the worker's action (and result as well) as follows:

- (Worker), operate controls of the saltwater ballast system from the cargo control room, discharging ballast in order to maintain a prescribed mean draft and position the vessel in trim condition for LNG cargo loading operations...

FJA provides guidelines for an action vocabulary in the worker functional orientation scales, shown in Appendix E.

Technical terminology is permissible as long as the terminology will be meaningful to anyone working in the field. This is the main criterion:

- If a worker read or heard the task description would he identify with it and recognize the task as his own? When the worker reads or hears the task description his thoughts should be, "Yes, that's what I do," not "Is that what I do?"

Analysts who have experience in the field have a great advantage in being familiar with the terminology. It helps them identify and use source information more readily for task writing and helps them write tasks that ring

true. However, the terminology can be a trap because it is assumed to have greater precision than common language. Specialized terminology can mean different things to different people and in different contexts. For example, anyone involved with ships is probably going to know what "trim condition" means (in the last example task description). That is a good use of the term; it evokes immediately an image that might be lost in verbiage if the analyst tried to explain it in common language. However, "trim" as a verb is not so clear. The action of trimming is different for different types of vessels. The error, however, was not in the use of specialized language; it was in the confusion of action with result. Experience indicates that awareness of this action/result distinction tends to eliminate problems concerning the use of terminology of the field. Most special terms originate as nouns; they are names given to results, products, processes. When those are turned into verbs, essential differences in the actions may be obscured.

Figure D.4 shows the development of a task description written by a new task analyst and critiqued by peers. The third draft provides significantly more information about what the worker does. The first draft focused on the expected result too much. In the third draft it is clear that the task is very simple--just turn dials and push buttons as directed by a short, step-by step procedure that does not have to be remembered, observe whether panel lights respond as they should, and record the completion of the task in a log. Figure D.4 also demonstrates that there is some leeway in using the model sentence. In the example task the tools/equipment/materials are not specified in a distinct "using what" clause. The work aids are the vapor detection console, the procedure mounted on it, the worker's own hands and eyes, the log, and a pen or pencil. Those are all clearly indicated in other elements of the task description. The primary purpose of the model sentence is to help the analyst make sure he considers all the elements of a task.

<u>Summary of Task Description Process</u>.

1. Select subsystem, goal, and objective.

2. Select task.

3. Use model sentence to write description of task in the most precise language possible.

4. Get someone to read the task description. Determine whether all elements are clear to the reader. Revise as indicated. (Feedback from a reader is very helpful when beginning to write task descriptions. As the analyst gains experience, he can omit this step since FJA includes two editing processes in which feedback will be obtained.)

5. When the task description seems adequate, write it in the task space on the task statement form and go to the next process.

MODEL SENTENCE FOR TASK DESCRIPTIONS

Worker, please __________, __________, and __________ (action)

In order to ____________________ (result)

Using ____________________ (tools, equipment, work aids)

Following ____________________ (prescribed instructions)

Using your own judgment as to __________ (what is left to worker's discretion)

TASK DESCRIPTION

(First Draft)	Test the salinity detection system in order to ascertain that audio-visual alarms are functioning, using the test panel on the evaporator control console, following the procedure outlined thereon, using your own judgment as to testing more sample points than required thereon.
(Second Draft)	Test the salinity detection system in order to visually check and record in log that the audio-visual alarms are functioning, using the test panel on the evaporation control console, following the 5-step sequential procedure mounted on the console and using your own judgment as to testing more sample points than required thereon.
(Third Draft)	Turn dials, push buttons, observe and sign off in log as to response of audio and visual signals on the salinity detection test panel in the engineroom, in order to verify that audio and visual alarms are working, following 5-step sequential procedure mounted on the test panel and using your own judgment as to whether to test more than the required sample of test points.

FIGURE D.4. EXAMPLE OF THE DEVELOPMENT OF A TASK DESCRIPTION

Assessment of Task Functional Level and Orientation

After writing the task description, the analyst is then faced with assessment of the functional level and orientation of the task. The following explanation of this step is adapted from Fine and Wiley's Functional Job Analysis (1971), referenced previously.

What workers do as they perform the tasks that make up their jobs, they do in relation to Data, People, and Things. All jobs involve the workers, to some extent, with information or ideas (Data), with clients or co-workers, (People), and with machines or equipment (Things). Workers function in unique ways in each of these areas. For example, when a worker's task involves him with machines or equipment (Things), the worker draws upon his physical resources (strength, dexterity, motor coordination, etc.). When a worker's task involves him with information or ideas (Data), the worker calls his mental resources into play (knowledge, thought, intuition, insight, etc.). When a worker's task involves him with clients, customers, and co-workers (People), the worker draws upon his interpersonal resources (empathy, courtesy, warmth, openness, guile, etc.). All jobs require the worker to relate to each of these areas and in doing so require him to draw upon his resources in each of these areas to some degree.

The concrete and specific actions which workers perform in relation to Data, People, and Things as they execute different tasks can probably be described in an infinite number of ways; that is, there are as many specific ways of expressing what workers do in relation to Data, People, and Things as there are specific tasks to be performed or unique content conditions to which there is only a handful of significant patterns of behavior (functions) which describe how workers use themselves in relation to Data, People and Things. Those patterns of behavior which can be articulated reliably have been defined in Worker Function Scales, among the primary tools of FJA, which provide a standardized, controlled language to describe what workers do in the entire universe of work. For example:

- In relation to information and ideas, a worker functions to compare, compile, compute, or analyze data.
- In interacting with clients, customers, and co-workers, workers serve, exchange information, coach, or consult with people.
- In using equipment, workers feed, tend, operate or set up machines and drive/control vehicles. Although each of these worker functions is performed under widely varying conditions, occurs over a range of difficulty, and involves different specific content, each, within its scope, calls for similar kinds and degrees of worker characteristics to achieve effective performance.

The functions in each of the three areas of Data, People, and Things, are defined by a Worker Function Scale, in which the performance requirements range from the simple to the complex. The scale is ordinal (that is, one in which any point on the scale includes lower levels and excludes higher levels). Thus the selection of a specific function to reflect the requirements of a particular task indicates that the task includes the lower functions and excludes the higher ones. Figure D.5 illustrates this concept. The complete Worker Function Scales are included in Appendix E. When scanning the Worker Function Scale for Data (for example), if the analyst selects the compiling function as the appropriate worker behavior to describe the way a worker must relate to information in a given task, he is deciding two things: (1) that the worker's performance is more complex than copying and less complex than analyzing; and (2) that the worker must be able to perform all or at least comprehend all the data functions below compiling, but does not have to be able to perform or comprehend higher functions such as analyzing or coordinating.

OVERVIEW OF WORKER FUNCTION SCALES

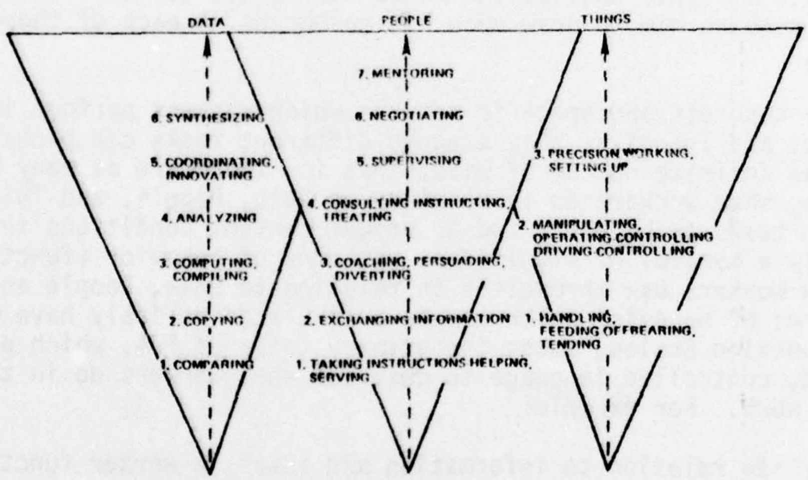


FIGURE D.5. SUMMARY CHART OF WORKER FUNCTION SCALES

The three hierarchies of Data, People, and Things functions provide two measures for systematically comparing and measuring the requirements of any task in any job. These two measures are level and orientation.

The level measure indicates the relative complexity or simplicity of a task when it compared to other tasks. It is expressed by selecting the function that best describes the pattern of behavior in which the worker engages to perform a given task effectively. The ordinal position of the function is the level measure. For example, to say that a worker in dealing with the Data content of a task is compiling, one has indicated that he is functioning at level 3B on the Data scale as shown in Appendix E. This requires a

higher level of functioning than is required in copying information (level 2) but is a lower level function than is required for analyzing data (level 4).

The orientation measure provided by FJA indicates the relative involvement of the worker with Data, People, and Things as he perform a given task. (Emphasis supplied.) The worker is not equally involved with all three in any task and his relative involvement with any of the three may change from task to task. For example, in performing one task in his job, a worker may be involved almost exclusively with Data; that is, something like 75 percent of his involvement and the resources he draws upon to perform a task are related to Data at the compiling level; but in order to accomplish the task, he must also be involved interpersonally in exchanging information with co-workers (perhaps 15 percent) as well as in calling upon physical resources in handling various documents, paper, and pen (10 percent). The worker's total functional involvement with Data (75 percent), People (15 percent) and Things (10) percent) adds up to 100 percent.

The orientation measure, then, is expressed by assigning a percentage in units of 5 or 10 to each of the three functions so that the total adds up to 100 percent. Note that these percentages are estimates. The reliability sought is in the pattern and proportion of the three estimates, not in the absolute amount of the estimates. (Emphasis supplied.)

The orientation measure is a reflection of the performance requirements of a task. In the example above, the estimates assigned must be in accord with the independent judgment that this task will be evaluated overwhelmingly on its data standards and quite lightly with regard to its people and things standards. The training the worker must have to perform the task should emphasize and build the mental skill required. The supervisor's instructions to the worker should emphasize and reflect the nature of the mental performance expected and the data standards by which the worker's results will be judged.

From the application of FJA to new technology ship occupations, some additional guidelines have been developed to assit in clarifying the FJA orientation measure.

The measure is seen as an indicator of the degree of worker concentration that is appropriate for the Data, People, and Things functions, relative to each other. The predominant function of a task, which should be foremost in the worker's awareness, is indicated by the desired result of the task. The relative prominence of the subordinate functions is suggested by the resources used to accomplish the task, how much they are used, and the care/precision with which they must be used in order to achieve the result. Task results can be categorized as data-, people-, or things-oriented. Task resources consist of data, people, and things.

The task described in Figure D.4 may be used as an example. The intended result of the task is verification of whether a system works. That is a data-oriented result. Thus the worker should focus on the data function in this task and the percentage which expresses the degree of the worker's

orientation toward data should be greater than the percentage expressing his orientation toward people or things.

Continuing with the example task, the worker must use <u>things</u> directly and deliberately, to accomplish the task result. He manipulates switches/buttons on a control panel according to a procedure. Thus he needs to concentrate on things to a substantial degree, although to a lesser degree than on the data function. The people function in this task should require minimal concentration. It consists of following instructions that in this case would be standing instructions. No personal interaction need occur.

The measure of the appropriate orientation to people in this task would be the least allowable percentage of the hypothetical total orientation -- i.e., 5%. That leaves 95% to be allocated to data and things. The data orientation receives the greater portion because the task is being performed to obtain data. Thus (given the rule of increments of 5%), the data orientation must be at least 50%. A things orientation of at least one-third is warranted, since the worker has to use things in a direct and premeditated way in order to generate the data by which the task result can be accomplished. With those boundaries, the data orientation should be in the range from 50% to 60%, and the things orientation in the range from 35% to 45%.

Hopefully, the foregoing will not suggest that determining orientation measure need involve an arduous and time-consuming thinking process. These measures typically are decided quickly, and equivalent measures (± 10%) are typically selected by different people, provided that the task is described clearly. The process is in essence intuitive.

It is stressed that the orientation measures are intended to establish the appropriate <u>relative</u> weights of the Data, People, and Things Functions in a task. The orientation measures indicate where emphasis should be placed in training, task performance, and performance evaluation.

<u>Steps in Assessing Task Level and Orientation.</u>

1. Scan the appropriate Worker Function Scale in Appendix E. A new analyst should read the scale completely through.

2. Compare the level definitions to the worker action phrase in the task description. (It may be necessary to revise the task description at this point.)

3. Select the level definition that best fits the worker's actions in relation to the function under consideration.

4. Record the level rating in the space for it on the Task Statement Form.

   (Do steps 1-4 for each functional area -- Data, People, and Things.)

5. Assign a percentage for orientation to Data, to People and to Things. Record the percentages in the spaces for them on the Task Statement Form.

When beginning to write task statements it is helpful to get one or more independent assessments of the level and orientation of the task. The independent readers should make their assessments and then discuss them. The task should be then reworded if necessary and reassessed until an agreement is reached (difference no more than one level on scale and no more than 5 percent in oridentation). Agreement tends to indicate the accuracy of the task description.

Assessment of Instructional Level

The next step toward the completion of the task statement deals with worker instructions. All work is a mix of precription and discretion; whatever is not prescribed is discretionary. High level tasks have a greater proportion of discretion in relation to the prescription.

The prescribed and discretionary mix of work is described in FJA by an ordinal scale called the Worker Instructions Scale. It will be found following the Worker Function Scales in Appendix E at the back of this report. The new analyst should read this Worker Instructions Scale fully to become familiar with its categories before trying to use it.

Each task description contains information about the instructions the worker received (the prescription) and what is left to the worker to decide (discretion). This information should be adequate to permit the analyst to determine the level of instructions on the Worker Instructions Scale. To illustrate, the instructions part of the sample task description (Figure D.4) reads as follows:

> ... following the 5-step sequential procedure mounted on the test panel and using your own judgment as to whether to test more than the required sample of test points.

Referring to Appendix E, these would be level 2 instructions. As stated in the scale definition for level 2, the "inputs and outputs are all specified, but the worker has some leeway about the procedures and methods he can use to get the job done." (Worker decides whether there is a need, and time, to test more than the required sample, and no time for testing is prescribed -- the worker usually decides at what time to do this daily task.) "Almost all the information he needs is in his assignment." (The information needed to decide whether to do more testing comes from the worker's experience; also, when to test may be determined by other conditions.)

The instructions rating should be compared to the data rating selected from the Worker Function Scale for Data. If there is a difference of more than one level between those two ratings, the two ratings should be rechecked. High-level instructions are not appropriate for a low-level data task, and vice versa.

Summary of Steps in Assessing Worker Instructions.

1. Scan the Worker Instructions Scale in Appendix E of this report. (A new analyst should read the scale completely through.)

2. Compare the level definitions to the phrase describing instructions in the task description.

3. Select the level definition that best fits the mix of prescription and discretion indicated by the task description.

4. Compare instructions level to data function level; reassess one or both if there is more than one level of difference between the ratings.

5. Revise task description if that is called for, and reassess.

6. Record the level of instructions (and the new data function level, if it has been revised) on the task statement form.

As with the Worker Function Scales, it is helpful in learning to use the Worker Instructions Scale to get an independent reader or readers to apply the scale to the task description. If the independent assessment does not agree with the analyst's (same rating or one level higher or lower), then both assessments and the wording of the task description should be discussed until a resolution of the difference is achieved.

Assessment of Basic Educational Skill Requirements

The Scales of General Educational Development (GED) presented in Appendix E provide a tool for determining the basic educational skill requirements necessary to perform a job at specified Things, Data, and People functional levels. Basic educational skills refer to reasoning, math, and language skills.

The level of skill the task requires in each of these basic areas is critical information to anyone setting qualification standards. The general education requirement for a job can best be set based on the actual requirements of the tasks assigned to workers in the job. Requirements set in this way have a much firmer foundation that those based on academic credentials. For example, "high school diploma" is a meaningless requirement unless it guarantees possession of certain skills (which it often does not), and only then if those skills are actually the ones needed for successful task performance. Arbitrary diploma and degree requirements are no guarantee to an employer and they may screen out capable, motivated people.

The GED Scales in Appendix E are ordinal, like the Worker Function and Worker Instructions Scales, and they are used similarly. The analyst

must consider the whole task description, but particularly the worker action and the instructions. He also considers the worker function levels and orientation. Those data should lead him naturally to the appropriate GED levels.

Summary of Steps in Assessing GED Requirements.

1. Scan one scale and identify the level of that skill that seems appropriate (A new analyst should read the scale completely through.)

2. Compare skill level definition with the definitions for the worker function levels of the task.

3. Compare skill level definition with the definition of the instructions level.

4. Does the skill level make sense in relation to others?

5. Does the skill level seem reasonable in relation to the task description wording?

6a. If the answers to 4 and 5 are yes, record the skill level on the task statement form and repeat steps 1-6 for the other two skill areas in turn.

6b. If the answer to 4 or 5 or both is no, evaluate scale levels and/or task description as appropriate, correct, and proceed to assess the other skill areas.

Again, it is helpful for a new analyst to get independent assessments of the GED Scale rating to compare to his own.

Determination of Performance Standards

The next step in completing an FJA task statement is to determine appropriate performance standards. These standards establish the rigor of any qualification testing that may be required. They provide a basis for evaluating the performance of candidates on such tests. The standards also will be important information for the development of training and measures of training outcomes.

Two types of performance standards are defined in FJA: descriptive and numerical. The developers of FJA explain the difference as follows.

Descriptive standards are performance criteria which are generally nonspecific and subjective; e.g., "please type this letter as quickly as possible;" be reasonably accurate in checking these figures;" "don't spend too much time in compiling this report;" "be as complete as possible in collecting the information." They tell in general terms what is expected; but they are wide open to interpretation.

Numerical standards are objective performance criteria which require no interpretation. They usually take the form of numerical or categorical statements; e.g., "please have this letter typed by 5:00 p.m.," "please double-check these figures to ensure that there are no errors." Since they are objective, they explicitly communicate the standards by which performance will be assessed.

In a given work situation, most workers learn through experience (which may be quite frustrating), how to interpret descriptive standards correctly and produce acceptable results. However, descriptive standards are inadequate by themselves for use in setting personnel qualifications. There are some tasks for which it is very difficult to specify numerical or categorical standards. However, if it is not possible or appropriate to be explicit about how the worker's action and the results are to be evaluated, then the task should not affect qualifications. In some cases, it might appear that there are no appropriate numerical or categorical standards at first, but they tend to become evident to the analyst as he writes descriptive standards. In other words writing descriptive standards may be like priming a pump.

Performance standards are determined according to common sense informed by the task description and the worker function scale levels. The worker orientation measure also must be considered. If a task is 80% thing-oriented, then the standard(s) should be set for the worker's functional level in relation to things. In that case, it is not necessary to set a standard for the results of the involvement with, say people, unless that involvement, though relatively minor as a percentage of total involvement, is critical and is not measured by the standard(s) set for things results. Such a situation is unlikely, and if it appears, the analyst should consider whether the task is actually two tasks that ought to be separated.

There is a rule of thumb that may be helpful in writing performance standards:

- If you were a new worker, what information would you need in order to know whether you did the task right?

Using this rule of thumb, and common sense, the analyst usually finds that performance standards flow from the other information in the task statement almost automatically.

Figure D.6. shows performance standards for the example task. Only one descriptive standard is recorded in Figure D.6. Since the example task is highly prescribed, it is easy to identify numerical/categorical standards. The one descriptive standard--"good judgment about when additional testing is needed"--led to an addition to the last categorical standard--"all anomalies of signal response noticed and checked out." This is an example of the pump-priming effect of writing descriptive standards mentioned earlier.

Determination of Training Requirements

This is the final step in completing a task statement and answers the following questions:

Performance standards should evaluate both the worker action (behavior) and the result (output), as exemplified below.

Task: Turn dials, push buttons, observe and sign off in log as to response of light signals on the salinity detection test panel in the engineroom, in order to verify that audio-visual alarms are working, following the 5-step sequential procedure mounted on the test panel console and using own judgment whether to test more than the required sample of test point. Data level, 50%; People Level 1A, 5%; Things Level 1C, 45%.

Performance Standards		What is Being Evaluated?	
Descriptive	Numerical/Categorical		
	Procedure followed exactly in 100% of tests	Action:	Executing all steps in prescribed sequence
	All test actions signed immediately on completion 100% of time	Action:	Keeping log up to date
	100% of required sample of test points checked daily	Action:	Checking all required test points daily
Good judgment about when additional testing is needed	All anomalies of signal response noticed and checked out	Result:	No failure of alarm system goes undetected because of inadequate testing

FIGURE D.6. EXAMPLE OF TASK PERFORMANCE STANDARDS

- What does a worker have to know and be trained to do in order to perform (the task) according to the standards indicated?

- How and where will he acquire this knowledge?

The FJA task statement is designed to provide answers to these questions in all the previous steps following the task description, in its functional and instructional level measures, its basic skill (GED) requirements measures and its performance standards.

Two types of skills are distinguished--functional and specific content skills:

Functional Skills refer to those competencies that enable an individual to relate to Things, Data, and People (orientation) in some combintation according to his personal preferences and to some degree of complexity appropriate to his abilities (level). They include skills like tending or operating machines; comparing, compiling, or analyzing data; and exchanging information with or consulting ana supervising people. These skills are normally acquired in educational, training, and avocational pursuits and are reinforced in specific job situations.

Specific Content Skills refer to those competencies that enable an individual to perform a specific job according to the standards required. These skills are normally acquired in an advanced technical training school or institute, or by extensive on-the-job experience. These skills are as numerous as the specific products or services which they produce or the standards and conditions established by employers under which they are exercised.

The reason for the distincition between these two types of skills becomes apparent from their definitions. They are acquired at different times and under different conditions, and too often the appropriate time and place for providing one is confused with the other. The confusion begins from the simple fact that functional skill training in schools must have some specific content. There is however, no reason to assume that the specific content of a specific job situation is accounted for in this type of training.

Sidney A. Fine has delineated the concept of three types of skills in order to comprehend better the nature of human performance. In addition to Functional and Specific Content Skills, he has proposed need for defining and comprehending Adaptive Skills. Adaptive Skills being those which permit a worker to respond correctly to a changing environement. However, since Adaptive Skills do not have a direct relationship to task statements formulated using the FJA technique, they are not dealt with here. It should be noted, however, that Adaptive Skills are regarded as crucial to a worker's job satisfaction and individual growth in a specific job.

Figure D.7. is a chart (from Fine and Bernotavicz, 1973) that provides examples of the three kinds of skills and summarizes some important concepts about them.

Kinds of skills	Examples	Where learned	Appropriate training situation and method
Functional Skills Competencies which enable people to relate to Data, People, and Things. They are expressed in terms of orientation and level.	Tending or operating machines; comparing, compiling, or analyzing data; exchanging information; consulting and supervising people.	School, training institutes, hobbies. Reinforced and developed on the job.	School situation--focus on principles, theories, and range of methods available to achieve desires result. Specific examples used with emphasis on transfer of principles.
Specific Content Skills Competencies which enable people to perform a specific job, using specific equipment, technology, and procedures. They are expressed in the specifics of a task statement.	As numerous as specific products, services, and employers who establish the standards and conditions under which those products and services are produced.	Advanced technical training school or institute, extensive on-the-job experience, or on-the-job training in a specific job.	Specialized schools or institutes. Orientation sessions for on-the-job procedures. On-the-job training either in training shop or through close supervision by supervision by supervisor or assistance from other workers.
Adaptive Skills Competencies which enable people to manage themselves in relation to the demands for conformity and/or change in response to the physical, interpersonal, and organizational conditions of a job.	Management of oneself in relation to authority; to impulse control; to moving towards, away from, or against others; to space (sense of direction and routing); to time (punctuality and self-pacing); to care of property; to dress (style and grooming).	In early childhood experiences, through family and peers; reinforced in school and work situations.	Informal situations, either in school or on the job. Group sensitivity sessions; one-to-one counseling; role-playing; simulation; problem- or crisis-centered techniques. Sensitivity sessions where management and workers come to agreement on accommodations which both can make.

FIGURE D.7. HUMAN PERFORMANCE: A COMPLEX OF THREE INTERRELATED KINDS OF SKILLS

As the chart indicates, the analyst gets functional skills directly from the levels and orientation measures for the task. Specific content skills come directly out of the specifics of the task description.

EDIT OF TASK STATEMENTS

Following completion of the task statements, the editing process begins. The purposes of the edit are:

- To assure that all content elements are included and that their wording in the task description is clear.
- To check whether the task description accurately represents the functional level and orientation, the instructional level and the basic skill requirements of the task.
- To check whether the performance standards and training content appear to be usable operationally (by workers, supervisors, and trainers) and are logically supportable in view of the other parts of the task statement.
- To determine whether the whole task statement gives a sense of reality about the task action and its context.

The edit is done by <u>individual</u> editors. The analysts who initially write the task statement may exchange them for this activity, or other people may perform the edit. The editors must be versed in the use of FJA, and it is helpful if they are knowledgeable about the field of the work system. (When the editor is not familiar with the field, he has to question the writer of the task statement more to clarify a task.)

<u>Summary of Editing Steps</u>

1. Editor reads task description and checks for completeness (all relevant content elements present) and clarity of wording.
2. Editor <u>independently</u> rates worker function level and orientation, worker instructions level, and basic skills (GED) levels, using FJA scales.
3. Editor evaluates performance standards and training content for (a) reasonableness in relation to task description and scale

ratings and (b) practicality (are the standards usable - can worker performance be assessed consistently against those standards; would the training content statements be useful in the development and evaluation of a training program).

The following is a checklist of specific questions to ask when editing task statements:

EDITING CHECKLIST

1. Does the end result of the task make a contribution to the organizational objective?

2. Are the worker action phrase and the result phrase of the task statement in reasonable relation to one another?

3. Does the task description, particularly the worker action phrase, adequately express the context of the task?

4. Does the language in the worker action phrase of the task statement support the worker function levels?

5. Do the worker action and the result phrases of the task statement support the orientation percentages assigned?

6. Is there more than a one-level spread between data, worker instructions, and reasoning scale ratings?

7. Is the result identified in the task a verifiable result?

8. Are the performance standards specified useful to a supervisor and to a worker?

9. Does the training content reflect the knowledge and abilities required to perform the task?

It has been found most useful if a small group of task statements is edited very shortly after the analyst begins writing them, so he can benefit from editing feedback before going on. Subsequent editing is best done on complete sets of task statements for an objective. Then the editor can check the completeness with which the objective is covered.

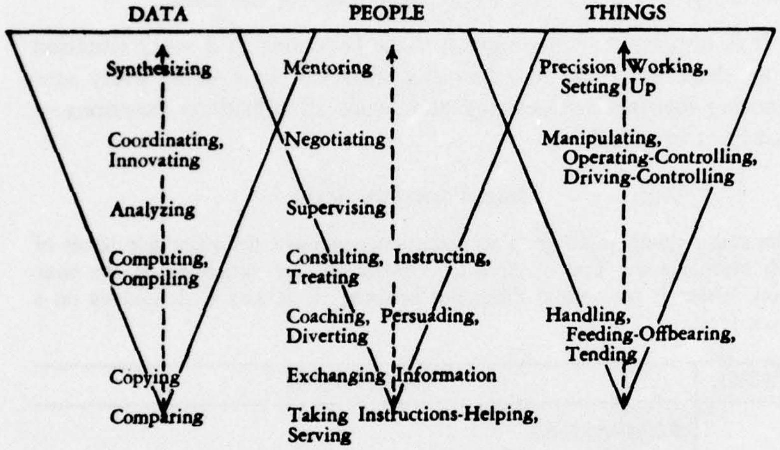
It is also most helpful if the editor and writer meet personally to discuss the editor's observations about the first set of task statements that is edited. They may reach a level of understanding at which they can communicate adequately in writing or by telephone if that is more convenient.

APPENDIX E

FUNCTIONAL JOB ANALYSIS (FJA) SCALES

Scales for Controlling the Language of Task Statements

Summary Chart of Worker Function Scales



Note: Each successive function reading down usually or typically involves all those that follow it. The functions separated by a comma are separate functions on the same level separately defined. They are on the same level because empirical evidence does not make a hierarchical distinction clear.

The hyphenated functions: *Taking Instructions-Helping, Operating-Controlling, Driving-Controlling,* and *Feeding-Offbearing* are single functions.

Setting Up, Operating-Controlling, Driving-Controlling, Feeding-Offbearing, and *Tending* are special cases involving machines and equipment of *Precision Working, Manipulating,* and *Handling,* respectively, and hence are indented under them.

Complete Version of Worker Function Scales

Data Function Scale

Data should be understood to mean information, ideas, facts, and statistics. Involvement with Data is inherent in the simplest job instruction in the form of recognizing the relationship of a tool to its function or the significance of a pointing instruction. Data are always present in a task even though the major emphasis of the task might be dealing with Things and/or People. Where Things are primarily involved, Data tend to show up as specifications. Where

People are primarily involved, Data tend to show up as information about objective events or conditions, information about feelings, or ideas that could be tinged with objective information and/or feeling. The Data Scale measures the degree to which a worker might be expected to become involved with Data in the tasks he is asked to perform from simple recognition through degrees of arranging, executing, and modifying to reconceptualizing the Data.

It is important to distinguish these functions in a work situation from those occurring in a learning situation. In a sense, every new learning involves synthesizing and hence all subsidiary functions — slowly or in a flash.

Data Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A, B,* and *C* definitions are variations on the same level. There is no ordinal difference between *A, B,* and *C* definitions on a given level.

LEVEL	DEFINITION
1	COMPARING Selects, sorts, or arranges data, people, or things, judging whether their readily observable functional, structural, or compositional characteristics are similar to or different from prescribed standards.
2	COPYING Transcribes, enters, and/or posts data, following a schema or plan to assemble or make things and using a variety of work aids.
3A	COMPUTING Performs arithmetic operations and makes reports and/or carries out a prescribed action in relation to them.
3B	COMPILING Gathers, collates, or classifies information about data, people, or things, following a schema or system but using discretion in application.

LEVEL	DEFINITION
	ANALYZING
4	Examines and evaluates data (about things, data, or people) with reference to the criteria, standards, and/or requirements of a particular discipline, art, technique, or craft to determine interaction effects (consequences) and to consider alternatives.
	INNOVATING
5A	Modifies, alters, and/or adapts existing designs, procedures, or methods to meet unique specifications, unusual conditions, or specific standards of effectiveness within the overall framework of operating theories, principles, and/or organizational contexts.
	COORDINATING
5B	Decides time, place, and sequence of operations of a process, system, or organization, and/or the need for revision of goals, policies (boundary conditions), or procedures on the basis of analysis of data and of performance review of pertinent objectives and requirements. Includes overseeing and/or executing decisions and/or reporting on events.
	SYNTHESIZING
6	*Takes off in new directions* on the basis of personal intuitions, feelings, and ideas (with or without regard for tradition, experience, and existing parameters) *to conceive new approaches* to or statements of problems and the development of system, operational, or aesthetic "solutions" or "resolutions" of them, typically outside of existing theoretical, stylistic, or organizational context.

People Function Scale

The substance of the live interaction between People (and animals) is communication. In the broadest sense the communication can be verbal or nonverbal. What gives communication its complexity is the heavy load that messages carry; e.g., Data in their objective and subjective forms — the way in which they are delivered (volume, tone, accompanying gesture, and the formal rules and informal customs that govern the context of the communication). Since there is a large subjective element on the part of both the sender and the receiver of a communication, it is very difficult to measure or to assign absolute values or primary importance to one or another type of information in the interaction.

What further complicates pinning down the nature of specific interpersonal behavior is that *affect* can serve as a *tool* for managing oneself in the interaction as well as the informational *substance* of the interaction. Affect, as information and as tool, can occur in the simplest as well as the most complex interactions. For example, affect expressed as a sulky manner, perhaps to gain attention or perhaps to express resentment on the part of an entry worker, can quickly become the informational substance of the interaction, when the supervisor asks nonreactively, "Don't you feel well?" and gets a positive answer, "No, I don't. My child is ill. I should be home!"

The functions in the People Scale deal with these complex questions only indirectly. The assumption of ordinality is somewhat more tenuous than in the Data and Things Scales and depends more heavily on role, status, and authority which are often associated with, but not necessarily a part of, skill. In effect, the functions try to capture the variety of interpersonal behavior *assigned* in various work situations and are more or less arranged, as in the other scales, according to the need, in general, to deal with increasing numbers of variables and with greater degrees of discretion. (The function least likely to fit this pattern is Supervising, which probably could have a scale of its own.)

Skill in dealing with People is undoubtedly as much an art as a methodology, and on every level it is especially necessary to delineate

the descriptive and numerical standards by which a function can be appraised in the task in which it occurs. This is true for the simplest function as well as the most complex. Admittedly, measurement in this area is in a primitive state, but significant beginnings have been made.

In delineating standards for People functions on different levels, one should especially note the cultural boundary conditions and how they moderate the expression of affect on all levels. We have in mind here the rules of courtesy in such a matter as Taking Instructions-Helping, diplomatic protocol in various types of Negotiating, and "rules" of behavior in patient-doctor Mentoring. These cultural boundaries undoubtedly have a very definite effect on the prescription and discretion mix of a particular functional level.

People Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A, B,* and *C* definitions are variations on the same level. There is no ordinal difference between *A, B,* and *C* definitions on a given level.

LEVEL	DEFINITION
	TAKING INSTRUCTIONS-HELPING
1A	Attends to the work assignment, instructions, or orders of supervisor. No immediate response or verbal exchange is required unless clarification of instruction is needed.
	SERVING
1B	Attends to the needs or requests of people or animals, or to the expressed or implicit wishes of people. Immediate response is involved.
	EXCHANGING INFORMATION
2	Talks to, converses with, and/or signals people to convey or obtain information, or to clarify and work out details of an assignment within the framework of well-established procedures.
	COACHING
3A	Befriends and encourages individuals on a personal, caring basis by approximating a peer or family-type relationship either in a one-to-one or small group situation; gives instruction, advice, and personal assistance concerning activities of daily living, the use of various institutional services, and participation in groups.
	PERSUADING
3B	Influences others in favor of a product, service, or point of view by talks or demonstrations.
	DIVERTING
3C	Amuses to entertain or distract individuals and/or audiences or to lighten a situation.
	CONSULTING
4A	Serves as a source of technical information and gives such information or provides ideas to define, clarify, enlarge upon, or

LEVEL	DEFINITION
	sharpen procedures, capabilities, or product specifications (e.g., informs individuals/families about details of working out objectives such as adoption, school selection, and vocational rehabilitation; assists them in working out plans and guides implementation of plans).
4B	INSTRUCTING Teaches subject matter to others or trains others, including animals, through explanation, demonstration, and test.
4C	TREATING Acts on or interacts with individuals or small groups of people or animals who need help (as in sickness) to carry out specialized therapeutic or adjustment procedures. Systematically observes results of treatment within the framework of total personal behavior because unique individual reactions to prescriptions (chemical, physical, or behavioral) may not fall within the range of prediction. Motivates, supports, and instructs individuals to accept or cooperate with therapeutic adjustment procedures when necessary.
5	SUPERVISING Determines and/or interprets work procedure for a group of workers; assigns specific duties to them (delineating prescribed and discretionary content); maintains harmonious relations among them; evaluates performance (both prescribed and discretionary) and promotes efficiency and other organizational values; makes decisions on procedural and technical levels.
6	NEGOTIATING Bargains and discusses on a formal basis as a representative of one side of a transaction for advantages in resources, rights, privileges, and/or contractual obligations, "giving and taking" within the limits provided by authority or within the framework of the perceived requirements and integrity of a program.
7	MENTORING Works with individuals having problems affecting their life adjustment in order to advise, counsel, and/or guide them according to legal, scientific, clinical, spiritual, and/or other professional principles. Advises clients on implications of analyses or diagnoses made of problems, courses of action open to deal with them, and merits of one strategy over another.

Things Function Scale

Working with Things means literally the physical interaction with tangibles, including taken-for-granted items such as desktop equipment (pencils, paper clips, telephone, handstamps, etc.); blackboards and chalk; and cars. Physical involvement with tangibles such as desktop equipment, etc., may not seem very important in tasks primarily concerned with Data or People, but it is quickly apparent when handicap or ineptness occurs. An involvement with Things can be manifested in requirements for the neatness, arrangement, and/or security of the workplace. Workers who make decisions or take actions concerning the disposition of Things (tools, materials, or machines) are considered to be working mainly with Data, although they physically handle Things (e.g., records, telephone, and catalogs).

Things Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A, B,* and *C* definitions are variations on the same level. There is no ordinal difference between *A, B,* and *C* definitions on a given level.

LEVEL	DEFINITION
	HANDLING
1A	Works (cuts, shapes, assembles, etc.), digs, moves, or carries objects or materials where objects, materials, tools, etc., are one or few in number and are the primary involvement of the worker. Precision requirements are relatively gross. Includes the use of dollies, handtrucks, and the like. (Use this rating for situations involving casual use of tangibles.)
	FEEDING-OFFBEARING
1B	Inserts, throws, dumps, or places materials into, or removes them from, machines or equipment which are automatic or tended/operated by other workers. Precision requirements are built in, largely out of control of worker.
	TENDING
1C	Starts, stops, and monitors the functioning of machines and equipment set up by other workers where the precision of output depends on keeping one to several controls in adjustment, in response to automatic signals according to specifications. Includes all machine situations where there is no significant setup or change of setup, where cycles are very short, alternatives to nonstandard performance are few, and adjustments are highly prescribed. (Includes electrostatic and wet-copying machines and PBX switchboards.)
	MANIPULATING
2A	Works (cuts, shapes, assembles, etc.), digs, moves, guides, or places objects or materials where objects, tools, controls, etc., are *several* in number. Precision requirements range from gross to fine. Includes waiting on tables and the use of ordinary portable power tools with interchangeable parts and ordinary tools around the home, such as kitchen and garden tools.

LEVEL	DEFINITION
	OPERATING-CONTROLLING
2B	Starts, stops, controls, and adjusts a machine or equipment designed to fabricate and/or process data, people, or things. The worker may be involved in activating the machine, as in typing or turning wood, or the involvement may occur primarily at startup and stop as with a semiautomatic machine. *Operating a machine* involves readying and adjusting the machine and/or material as work progresses. *Controlling equipment* involves monitoring gauges, dials, etc., and turning valves and other devices to control such items as temperature, pressure, flow of liquids, speed of pumps, and reactions of materials. *Includes the operation of typewriters, mimeograph machines, and other office equipment where readying or adjusting the machine requires more than cursory demonstration and checkout.* (This rating is to be used only for operations of one machine or one unit of equipment.)
	DRIVING-CONTROLLING
2C	Starts, stops, and controls the actions of machines for which a course must be steered or guided in order to fabricate, process, and/or move things or people. Actions regulating controls require continuous attention and readiness of response. (Use this rating if use of vehicle is required in job, even if job is concerned with people or data primarily.)
	PRECISION WORKING
3A	Works, moves, guides, or places objects or materials according to standard practical procedures where the number of objects, materials, tools, etc., embraces an entire craft and accuracy expected is within final finished tolerances established for the craft. (Use this rating where work primarily involves manual or power handtools.)
	SETTING UP
3B	Installs machines or equipment; inserts tools; alters jigs, fixtures, and attachments; and/or repairs machines or equipment to ready and/or restore them to their proper functioning according to job order or blueprint specifications. Involves primary responsibility for accuracy. May involve one or a number of machines for other workers or for worker's own operation.

Scale of Worker Instructions

LEVEL	DEFINITION
1	Inputs, outputs, tools, equipment, and procedures are all specified. Almost everything the worker needs to know is contained in his assignment. He is supposed to turn out a specified amount of work or a standard number of units per hour or day.
2	Inputs, outputs, tools, and equipment are all specified, but the worker has some leeway in the procedures and methods he can use to get the job done. Almost all the information he needs is in his assignment. His production is measured on a daily or weekly basis.
3	Inputs and outputs are specified, but the worker has considerable freedom as to procedures and timing, including the use of tools and equipment. He has to refer to several standard sources for information (handbooks, catalogs, wall charts). Time to complete a particular product or service is specified, but this varies up to several hours.
4	Output (product or service) is specified in the assignment, which may be in the form of a memorandum or of a schematic (sketch or blueprint). The worker must work out his own ways of getting the job done, including selection of tools and equipment, sequence of operations (tasks), and obtaining important information (handbooks, etc.). He may either carry out work himself or set up standards and procedures for others.
5	Same as (4) above, but in addition the worker is expected to know and employ theory so that he understands the whys and wherefores of the various options that are available for dealing with a problem and can independently select from among them. He may have to do some reading in the professional and/or trade literature in order to gain this understanding.

LEVEL	DEFINITION
6	Various possible outputs are described that can meet stated technical or administrative needs. The worker must investigate the various possible outputs and evaluate them in regard to performance characteristics and input demands. This usually requires his creative use of theory well beyond referring to standard sources. There is no specification of inputs, methods, sequences, sources, or the like.
7	There is some question as to what the need or problem really is or what directions should be pursued in dealing with it. In order to define it, to control and explore the behavior of the variables, and to formulate possible outputs and their performance characteristics, the worker must consult largely unspecified sources of information and devise investigations, surveys, or data analysis studies.
8	Information and/or direction comes to the worker in terms of needs (tactical, organizational, strategic, financial). He must call for staff reports and recommendations concerning methods of dealing with them. He coordinates both organizational and technical data in order to make decisions and determinations regarding courses of action (outputs) for major sections (divisions, groups) of his organization.

Scales of General Educational Development*
Reasoning Development Scale

The Reasoning Development Scale is concerned with knowledge and ability to deal with theory versus practice, abstract versus concrete, and many versus few variables.

LEVEL	DEFINITION
1	• Have the common sense understanding to carry out simple one- or two-step instructions in the context of highly standardized situations. • Recognize unacceptable variations from the standard and take emergency action to reject inputs or stop operations.
2	• Have the common sense understanding to carry out detailed but uninvolved written or oral instructions. • Deal with problems involving a few concrete variables in or from standardized situations.
3	• Have the common sense understanding to carry out instructions furnished in written, oral, or diagrammatic form. • Deal with problems involving several concrete variables in or from standardized situations.
4	• Have knowledge of a system or interrelated procedures, such as bookkeeping, internal combustion engines, electric wiring systems, nursing, farm management, ship sailing, or machining. • Apply principles to solve practical, everyday problems and deal with a variety of concrete variables in situations where only limited standardization exists. • Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form.
5	• Have knowledge of a field of study (engineering, literature, history, business administration) having immediate applicability to the affairs of the world. • Define problems, collect data, establish facts, and draw valid conclusions. • Interpret an extensive variety of technical material in books, manuals, texts, etc. • Deal with some abstract but mostly concrete variables.
6	• Have knowledge of a field of study of the highest abstractive order (e.g., mathematics, physics, chemistry, logic, philosophy, art criticism). • Deal with nonverbal symbols in formulas, equations, or graphs. • Understand the most difficult classes of concepts. • Deal with a large number of variables and determine a specific course of action (e.g., research, production) on the basis of need.

*These scales have been modified and adapted by Sidney A. Fine from a table of "General Educational Development" in third edition, *Dictionary of Occupational Titles*, Vol. II (Washington: 1965), p. 652.

Mathematical Development Scale

The Mathematical Development Scale is concerned with knowledge and ability to deal with mathematical problems and operations from counting and simple addition to higher mathematics.

LEVEL	DEFINITION
1	• Counting to simple addition and subtraction; reading, copying, and/or recording of figures.
2	• Use arithmetic to add, subtract, multiply, and divide whole numbers.
3	• Make arithmetic calculations involving fractions, decimals, and percentages.
4	• Perform ordinary arithmetic, algebraic, and geometric procedures in standard practical applications.
5-6	• Have knowledge of advanced mathematical and statistical techniques such as differential and integral calculus, factor analysis, and probability determination. • Work with a wide variety of theoretical mathematical concepts. • Make original applications of mathematical procedures, as in empirical and differential equations.

Language Development Scale

The Language Development Scale is concerned with knowledge and ability to deal with oral or written language materials from simple instructions to complex sources of information and ideas.

LEVEL	DEFINITION
1	• Cannot read or write but can follow simple oral, "pointing-out" instructions. • Sign name and understand ordinary, routine agreements when explained, such as those relevant to leasing a house; employment (hours, wages, etc.); procuring a driver's license. • Read lists, addresses, safety warnings.
2	• Read comic books, "true confession" or "mystery" type magazines (short sentences; simple, concrete vocabulary; words that avoid complex Latin derivations). • Converse with service personnel (waiters, ushers, cashiers). • Copy verbal records precisely without error. • Keep taxi driver's trip record.
3	• Read material on level of the *Reader's Digest* and straight news reporting in popular "mass" newspapers. • Comprehend ordinary newscasting (uninvolved sentences and vocabulary with focus on events rather than on their analysis). • Copy verbal material from one record to another, catching gross errors in grammar. • Fill in report forms, such as Medicare forms, employment applications, and card form for income tax. • Conduct house-to-house surveys to obtain common census-type information or market data, such as preferences for commercial products in everyday use.

LEVEL	DEFINITION
4	• Have language ability to take and transcribe dictation, make appointments, and sort, route, and file the mail according to subject. • Write routine business correspondence reflecting standard procedures. • Interview job applicants to determine work best suited for their abilities and experience; contact employers to interest them in services of agency. • Understand technical manuals and verbal instructions, as well as drawings and specifications, associated with practicing a craft. • Guide people on tours through historical or public buildings, tell relevant anecdotes, etc. • Conduct opinion research surveys involving stratified samples of the population.
5	• Write instructions for assembly of prefabricated parts into units. • Write instructions and specifications concerning proper use of machinery. • Write copy for advertising. • Report news for the newspapers, radio, or TV. • Prepare and deliver lectures for audiences that seek information about the arts, sciences, and humanities in an informal way. • Report, write, or edit articles for magazines which, while popular, are of a highly literate nature (e.g., *New Yorker, Saturday Review, Scientific American*).
6	• Report, write, or edit articles for technical and scientific journals or journals of advanced literary criticism (e.g., *Journal of Educational Sociology, Science, Physical Review, Daedalus*). • Prepare and draw up deeds, leases, wills, mortgages, and contracts. • Prepare and deliver lectures on politics, economics, education, or science to specialized students and/or professional societies. • Comprehend and apply technical engineering data for designing buildings and bridges. • Comprehend and discuss literary works of a highly symbolic nature, such as works in logic and philosophy (e.g., Kant, Whitehead, Russell).

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